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METALS & ALLOYS

Devoted to the Advancement of Scientific Metallurgy

259

Nickel and Chromium Extend the Field of Application of Iron Castings

F. B. COYLE

Melting, Mechanical Working and Some Physical Properties of Rhodium

Wm. H. SWANGER

Light Alloys

ZAY JEFFRIES

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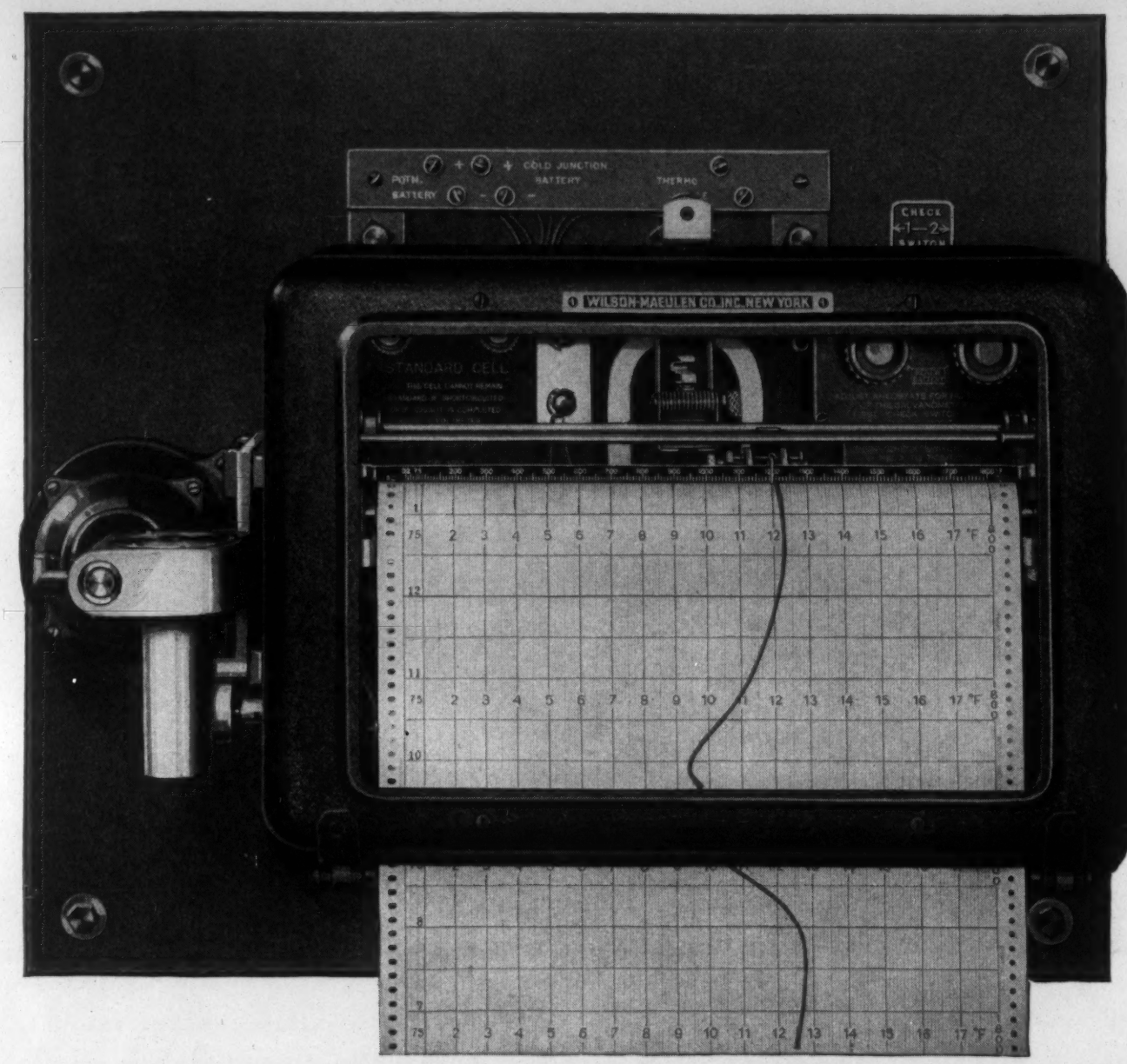

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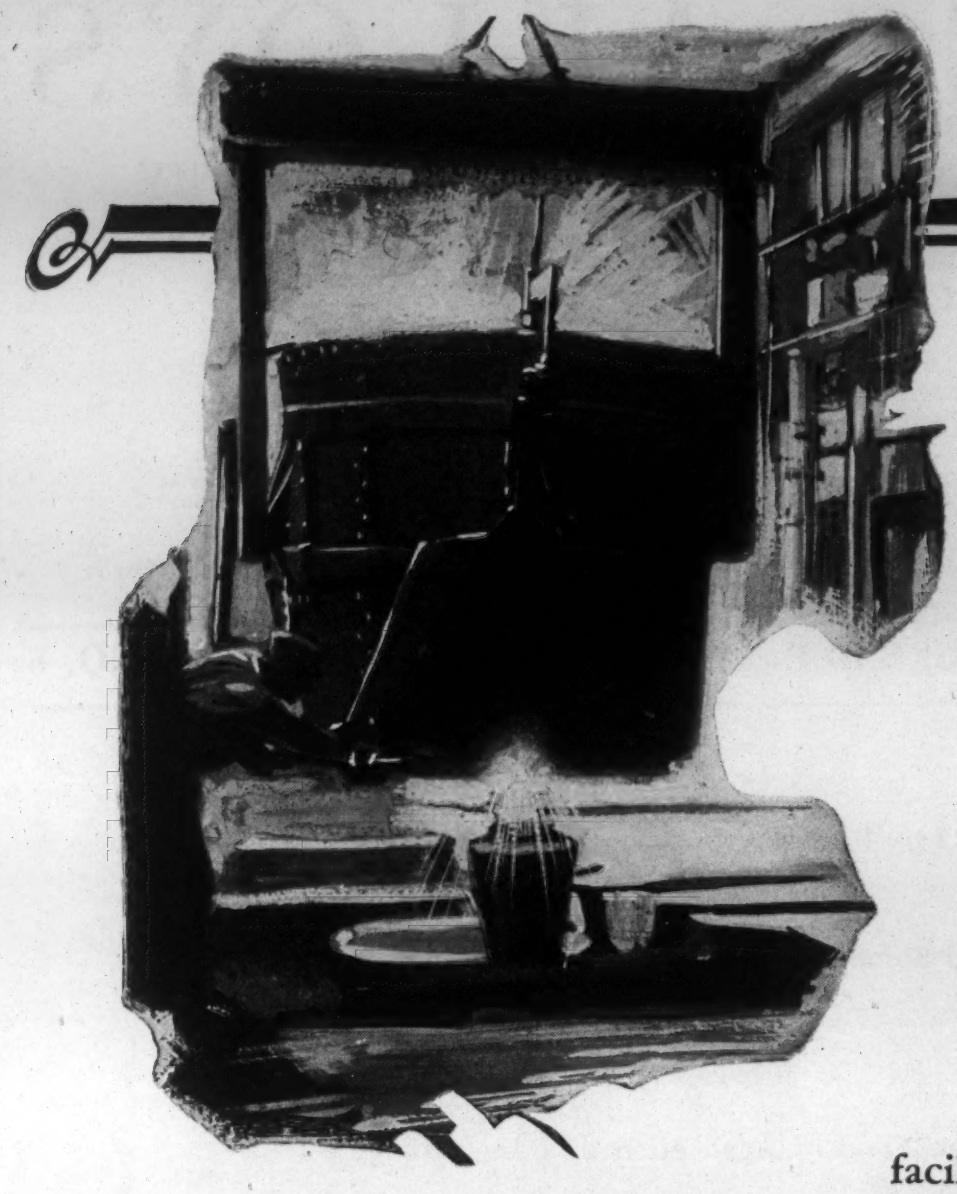

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PUBLISHER'S PAGE

Note— On this page the publishers will talk right straight to you each month. We will tell you how things are progressing with METALS & ALLOYS. *We will undoubtedly ask your advice on many points. We are publishing this paper not primarily to please ourselves but rather to serve you. And our office door is always open. You are invited to call.*

Special Information Service for Readers of METALS & ALLOYS

Several of our readers have written to us recently to inquire the names of manufacturers of or dealers in a number of materials and items of equipment concerning which they desired information, and which were not covered in the advertisements appearing in METALS & ALLOYS.

It is inevitable when a new paper is being started that the advertising section at the beginning should be very incomplete. Manufacturers do not like as a rule to advertise in a new publication for fear that it may not be successful and they prefer usually to wait until at least a few issues have been published so that some idea may be gained as to the probable success or failure of the enterprise. We have made no great effort to sell space in our advertising section, preferring to wait until the manufacturers can see for themselves that the paper is past the experimental period.

In the meantime we invite our readers to apply directly to us for information concerning any articles in which they are interested and which they have failed to find in the advertising section. We have already established a pretty complete file of everything likely to interest the scientific metallurgist and as we really desire to serve our readers in every way we possibly can we wish to invite you to make the fullest use of our facilities.

You may or may not have noticed the department devoted to the reviews of manufacturers' literature which appears on page 310 of this issue. We would like to know whether the descriptions of new pieces of printed matter as listed there are sufficiently extended to convey all necessary information regarding the various items or whether longer reviews going more into detail regarding the contents of each catalog or booklet would be of greater service to you. We have purposely condensed these items in order to include a considerable number on the page but if there is any general opinion to the effect that the items should be amplified we would of course be guided accordingly.

Remember, do not hesitate to communicate with us whenever you require any special information which you feel we might be in a position to furnish.

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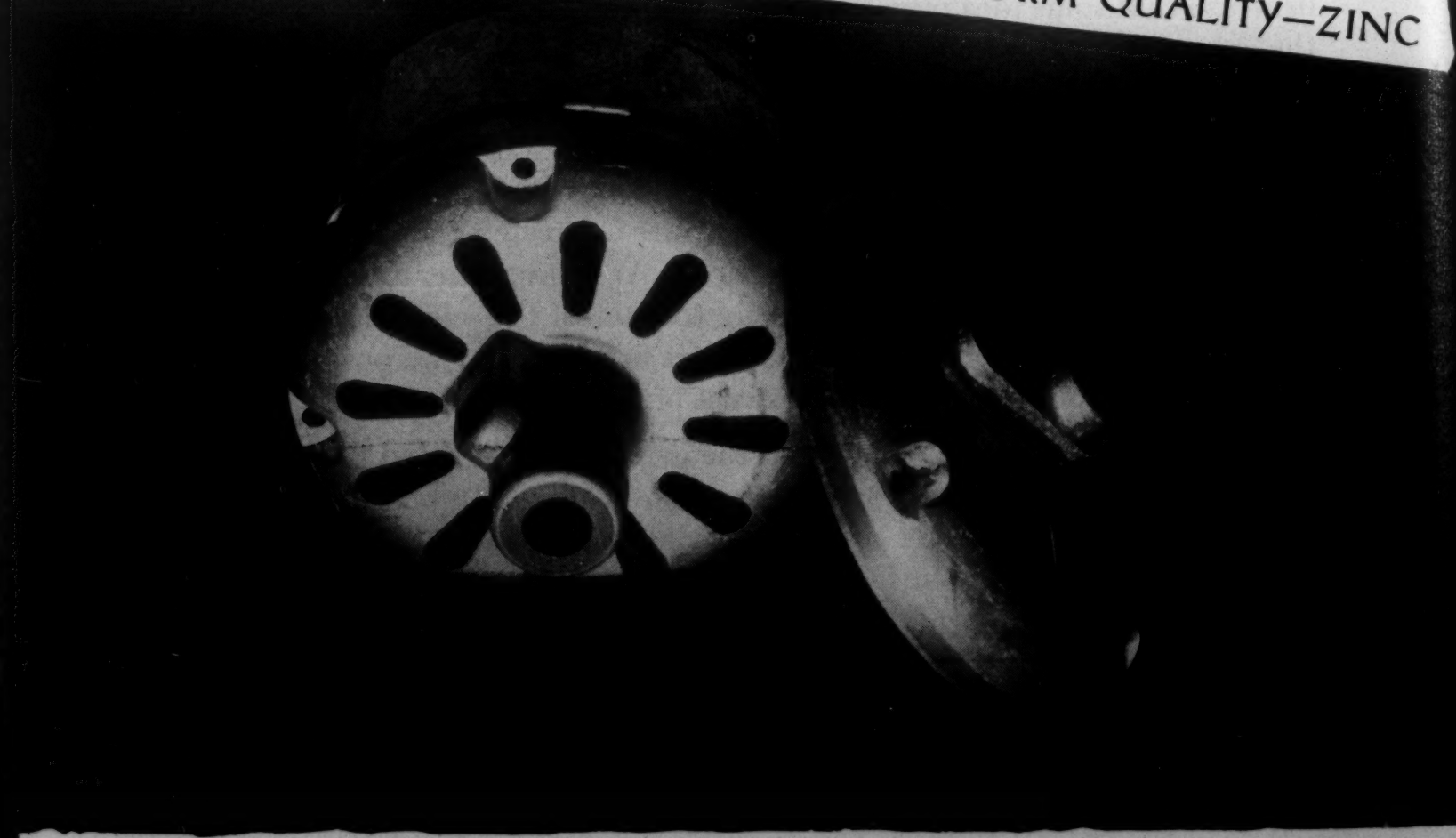

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Editorial Comment

In this department I try to comment on metallurgical and allied matters that seem to me interesting and significant. The views expressed reflect my own personal attitude. Many of our readers will have ideas of their own on these subjects and are urged to contribute them in the form of letters which will gladly be published in succeeding issues.—H. W. GILLETT, *Editorial Director.*

Alloy Steel and the "Alloys of Iron Research"

In alloy steel, 2 + 2 seldom equals 4. Starting with a plain carbon steel of a given carbon content with just enough silicon and manganese to control the oxygen and sulphur, we may add to it such alloying elements as Si, Mn, Cu, Ni, Cr, V, Mo, W, Co, Al, to omit the scavengers Zr and Ti, elements like P, S, Sn and As which we normally do not want, and the newer possibilities such as Be, Ta, etc.

Each of the alloying elements has its own idiosyncrasies. It is cheap or costly, domestic or imported, easy or mean to handle, and it confers quite definite properties upon the steel.

Foremost among the individual points of behavior is the action of each element in relation to the carbon content of the steel. Broadly speaking, we may strengthen steel by almost any of these elements, but when we do we must regulate the carbon content far more closely than in a straight carbon steel. If we pile up strength by adding alloy to a steel of medium carbon, we soon get brittleness. The optimum strength and toughness is usually achieved by cutting the carbon as we add alloy. If we do not balance the alloy steel properly, our equation becomes 2 + 2 = 1.

On the other hand, if, with due regard to carbon content, we use not one, but two alloying elements, it is generally possible to use less of each than would have been predicted. Some pairs of alloying elements go together, like pork and beans or ham and eggs, to give a more acceptable result than either alone. Thus, we have the Ni-Cr, Cr-V, Cr-Mo, Ni-Mo, Si-Mn, Cr-Al, Mn-Cr, Ni-Si and various other combinations, giving for specific purposes results leading to the equation 2 + 2 = 7. This may go on up to such combinations as W-Cr-V-Co high-speed steel and Ni-Cr-Mn-Mo die block steel. These are not "Irish stew" alloys in which a little of whatever you have around is put in to get rid of it, or to produce something you can get a patent on, but they are built up with due regard to individual properties conferred by each element, and to the way each lends a helping hand to the others, compensating by its virtues for something the others lack.

And, as the complexity of the steel increases, the ever-present question of how the carbon content must be adjusted to fit the particular alloying combination used has to be separately examined. In recent years, we have learned that carbonless alloys of iron and W, Mo, etc., can be hardened by heat-treatment and, if not steels by definition, these are steels by virtue of their properties. On the other end of the scale, we have the 2% C, 12% and higher Cr steels.

We have found that an alloy that will do a job in a superior fashion need not sell for 3¢ a pound, even if it does happen to contain a lot of iron. We knew this in regard to high-speed steel and Hadfield manganese steel, but it took longer to realize that the price could be paid for alloys of 22% Mo, of 25% or more Cr, of 35% Ni (the Invar type for aluminum piston struts), the austenitic corrosion resistant alloys, 18% Cr + 8% Ni, 25% Ni + 17% Cr + 2½% Si, and even such alloys as those with 35% Co, 7% W, 2% Cr for magnets or with 60% Ni, 20% Mo, 20% Fe for resistance to HCl, and the interesting Permalloy group with around 78% Ni. In heat-resistant alloys, the Ni-Cr-Fe-W and many other combinations are coming along in which the iron may or may not be sufficient for the alloy to class as steel. Metallurgical theory is not concerned about where alloy steels end, and alloys of iron begin, or about whether the iron preponderates or not. From the cost point of view, the amount of cheap or of expensive elements is important.

Before the highly-alloyed materials could come into commercial being, it was necessary that the electric furnace be developed. Such alloys, as well as high-speed steel, are today essentially the product of the electric furnace. With 100-ton electric furnaces in operation, electric steel and tonnage steel are not entirely incongruous terms.

It was also necessary, to make it practical to produce many of the high-chromium alloys in which carbon must be kept low, that low-carbon ferro-chromium be made commercially available.

The coming of low-carbon ferro was largely brought about by the advent of stainless steel. Every household had its stainless steel paring knife, and everyone came to realize that, for a price, rust-resistance was attainable. As the ranges of carbon lower than are used in stainless cutlery were explored, the possibilities of the high-chromium steels became evident for corrosion resistance and for structural strength. Such alloys are now becoming a tonnage proposition. In one nitric acid plant, recently constructed, 500 tons of chromium iron or stainless steel were used for towers, tanks and pipes. Architectural and decorative use of stainless and austenitic stainless steels also accounts for a really large tonnage.

While stainless steel and so-called stainless iron, also, are heat-treatable to very good properties as structural material, most of the other high-alloyed combinations are not ordinarily quenched and tempered. In the automobile industry, using heat-treated steels and constantly looking for ways of lowering the cost, there has been a trend toward lower alloy content. Instead of 3½% Ni, 1½% Cr as a representative alloy steel for heat-treating, or a 5% Ni steel for carburizing, the principle is to use just as little of the alloying element as will produce the desirable result, with suitable heat-treatment. Since many parts had to be machined after treatment, there was no gain in using steels inherently capable of giving optimum properties at hardness much above the machinable limit. The advent of grinding instead of machining, and of the new tungsten carbide tools, may produce some reaction toward use of more highly alloyed steels, but at any rate the automobile industry is not going to use any more alloying element than the particular case requires. Hence, we find Ni Cr steels for automobile work trending more toward the 1% Ni ½% Cr grade. When severe service requires the maximum possible properties, as in trucks, buses and tractors, the trend is rather in the opposite direction. Both trends are toward fitting the alloy steel to its job in the most economical fashion, all factors considered.

The advent of molybdenum, in large domestic supply and at lowered prices, has allowed the general use of a little Mo to improve the depth-hardening properties and to avoid temper-brittleness. On account of its welding qualities and its ability to air-quench to just the right degree, Cr Mo tubing of around 0.30% C, 1.00% Cr, 0.20% Mo is now practically standard for construction of airplane fuselages, and this is getting to be a tonnage use in the aggregate. It is estimated that about 3000 tons of alloy tubing are thus used per year in the United States.

Outside of automotive uses and uses requiring similar heat-treated alloy steel parts of relatively small cross-section, truly tonnage uses so far lie in non-quenched steels.

Carbon vanadium steel is in high favor for some large forgings of the type used in locomotive construction because of the good properties resulting from a simple normalizing treatment, and this has built up into a tonnage use, though only around 0.20% V is required. The expected tonnage for 1930 of vanadium alloy steel with this V content is over 300,000 tons.

The old use of 3½% Ni steel in armor plate, since limitation of naval construction, no longer requires so large a tonnage. But there are signs that a tonnage use as boiler plate may develop, and the standard of comparison for high strength steel for bridges is nickel steel.

The greatest tonnage of alloy steel is that to which copper, in addition to that found in the ore and scrap, is added to bring the copper content to about 0.25%, this steel being widely used for sheet and other products exposed to atmospheric corrosion, since sometimes there is a certain added resistance to corrosion, though the improvement is of a very low order of magnitude in comparison with the high Cr or high Ni high Cr rustless steels. In the amounts in which copper is used in the "copper bearing" steels, it has almost no recognizable effect on the strength, being used only for corrosion resistance, but some copper can apparently be used to advantage as a partial replacement for Ni in Ni and Ni Cr steels. Although Cu is one of the cheapest of the alloying elements, relatively little is known about its behavior in steel, either alone or in conjunction with other alloying elements, in comparison to what is known about more expensive elements.

Nickel and copper lend themselves to large tonnage open-hearth production because they oxidize less readily than iron itself, and hence introduce no slag complications, and are not lost on remelting scrap.

The cheap element silicon has long been used in transformer sheet, but although silicon steel was used in building the Lusitania and Mauretania about 25 years ago, interest in silicon as an alloying element in structural steel lagged till a few years ago when the Germans, trying to design their bridges and structures to take advantage of a high yield point, became much excited over a 0.15% C steel with 1 to 1¼% Si, and nearly 1% Mn. Difficulties in edge-cracking on rolling, perhaps surmountable with more care in melting practice, cooled the interest in that steel, and German interest centers at the moment in a low-alloy structural steel containing both Cr and Cu.

American practice in cheap structural alloy steel has developed along the lines of a manganese steel, with around 1% Mn, and with Si slightly higher than in ordinary steel, though, oddly enough, this is referred to as a "silicon" steel instead of a manganese steel. This has been used in 1000-ton lots in structures like the Delaware River bridge. The Port of New York Authority is now going ahead with a large bridge installation of a steel even higher in Mn, about 1.60%, and with higher carbon than one might have expected they would dare to use. Tonnage production of these structural Si or Mn steels is attended by much scrap until everything is tuned up, and consequently the mills are not interested in 50-ton orders of a special composition.

Manganese alloy steel is also finding use as a cheap and useful steel for carburizing. Manganese added to screw stock makes that product a somewhat respectable material of construction.

In the rails situation, there is dire need for rails of better properties. Discussion now rages as to the relative merits of heat-treatment of carbon steel in the heavy and irregular sections of modern rails, and of alloy rails without heat-treatment. After early experience, in which the usual mistake was made of using too much carbon in conjunction with an alloy element, a better balanced composition was evolved with around 0.60% C, 1.60% Mn. Quite large tonnages of this are being used. The latest arrival in alloy rails is a steel with 0.25% C, 3% Cr which, notwithstanding its low carbon, is harder and apparently more wear resistant than ordinary rail steel, and combines with this a high toughness.

Besides all the other special-purpose steels, we now have a new group, those for nitriding purposes, such as the Al-Cr, Al-Mo or more complex compositions.

About 3¼ million tons of alloy steel castings and forgings were made in 1928, an increase of 27% over the preceding year.

This brief survey could be very greatly extended to show how ramified the field is, and how intensive exploration of the properties of steels with almost any pair or trio of alloying elements results in finding a combination that is especially good for some special purpose.

A vast deal of work has been done, and is being done, in all steel-producing countries, and there are so many publications on this or that tiny corner of the field that no human being can keep up with the staggering mass of data, and pretend to do anything else.

Not only is this true in regard to wrought steel, but all the alloying elements are finding their way into cast steel and cast iron. The growth of alloy cast iron in the past few years is nothing short of amazing. Moreover, the advent of Aston wrought iron offers possibilities, not present in the old process, for the production of alloy wrought iron. Not very far out of the alloy steel picture are the new tungsten carbide tools, with analogous possibilities for the development of more complex binary and ternary carbide mixtures for specific purposes.

Study of the alloys of iron must then cover not only a few percent of the alloying element, but must run all the way from 0 to 100% and the effect of the alloy must be found in carbonless iron and with all ranges of carbon content up to, say, 4%, or far higher in the case of the carbides. The precise study of the system—iron, carbon and a single alloying element—is no small job, and when we come to two, three and more alloying elements, the metallurgist should be a Methuselah to do a complete job. Nevertheless, by the combined labor of many investigators armed with the X-ray spectrograph as well as the older tools, we are getting pretty reliable data on some of the simpler systems. Work on the alloys of iron with Ni, Cr, Mn, Si, Mo, W and V with varying carbon has now advanced so far, both from the scientific and practical points of view, that if the data could be so condensed and codified (in a manner similar to that employed by the legal fraternity in collecting all the decisions of all judges into usable form in legal "digests" properly classified) we might have a pretty clear idea of the multitude of facts and of the essential guiding principles governing the effect of alloying elements.

We need a constant flow of new data. We need abstracts which tell us where to find it, and which give an inkling of the results of the researches. But, most of all, we need to get all the data, old and new, into such shape that we can assimilate it, remember the high spots, readily find the details, and *use* it all. Also, we need a calm survey of the situation to see what facts are really proven, what things are doubtful and demand further study, and what gaps in the information should be filled by further experiment.

We can't each do this and hold any other job. We ought to be willing to pay a few qualified people to do work that thousands want and need. This is just what the Engineering Foundation "Alloys of Iron Research" project proposes to do—delegate to a group, which will do the job for us, the task of codification of the multitudinous scattered information on iron alloys that exists in all languages.

To us, this appears to be the most important job in ferrous metallurgy for the next few years. It is far more necessary, from the point of view of general metallurgical advancement than any new laboratory research. It deserves the services of our best metallurgists.

When we get the information that is already available in shape so we can tell what is known, and can use it, then we can proceed to add to that knowledge without having to duplicate the work already done. But for the present, we had best digest one Thanksgiving dinner before eating another.

The Alloys of Iron Research, well carried out, as it is sure to be under the guidance of Professor Waterhouse, will be an epochal service.

Readers' Views and Comments

To the Editor of METALS & ALLOYS:

Dear Sir: The résumé of Mr. Sam Tour's A. S. T. M. paper on "Aluminum Alloys for Pressure Die Castings" which was published in your October, 1929, issue appears likely to create more antagonism to specifications in general than was probably intended. Your caustic comment that too many specifications are the result of the exhaustion of committees responsible for their development does not appear to the writer as a fair appraisal of A. S. T. M. activities in any event.

Specifications furnish a common language for the use of the seller and the buyer. The requirements should assist the purchaser in obtaining what he requires and should enable the producer to fix the price at an economic level. The extent to which the specification can be made specific and pertinent determines to a considerable extent the efficiency of the transaction. It is probably impossible in the majority of cases for any initial draft of a specification to fully meet these ideal requirements. A. S. T. M. specifications are therefore issued initially in tentative form to permit users to determine their suitability.

The proposed specifications for aluminum base die casting alloys discussed in Mr. Tour's paper and in your résumé furnish an excellent example of the possible usefulness of tentative specifications. It is anticipated that an initial draft of specifications for aluminum base die casting alloys will be offered to the Society in June, 1930. These specifications will be based to a considerable extent on upwards of 50,000 tests of die cast specimens. Their chief merit, however, will lie in the fact that the diverse interests represented on the committee will make the specifications express the best judgments of producers and consumers of die castings. The first draft of the specifications will probably be faulty in certain respects. It is sincerely to be hoped that the committee will not succumb to slumber before the first year's publication as tentative use elicits comments based on users' experiences. The committee is assured that the specifications will be used as soon as available.

An attempt will be made in the first draft to limit the content to essential requirements insofar as possible and not to make the specification either useless to the buyer or impossible for the seller. Much about these alloys, including the effect of varying percentages of impurities, will still be in the controversial stage when this tentative draft is issued. However, it is believed that certain essential characteristics of die castings are known and that incorporation of such information in a specification will react to the benefit of both sellers and users of such products. The situation may be likened to that of a tourist in a foreign country who can make much better progress if he knows a few words of the language which assist in supplying his most elementary needs than if the native and the traveler have absolutely no phrases in common.

An incomplete specification is better than no specification at all and probably a specification with minor inaccuracies will be more conducive to progress than indefinite delay until the impossible 100% information is available.

HARVEY A. ANDERSON
American Society for Testing Materials

Editor's Note:

We have had no intention of criticising the excellent work of the A. S. T. M. Die Casting Committee. Instead, we would cite it as a model case in which the facts are being sought by exhaustive investigation before specifications are drawn.

We really had in mind such situations as exist in drawing up certain Federal specifications where, if two departments of the Government request it, a specification must be drawn. While years of delay may intervene, sooner or later a specification issues. The board which prepares the specification does not necessarily contain experts on every problem that comes before it, and, while counsel is sought and the specifications pass a gauntlet of criticism from maker and user, some specifications are so indefinite as to be worthless and some prove later to be badly in error. Most of the specifications are very good. The poor ones are generally traceable to lack of precise information. The board has no funds for research, and must depend on exciting the interest of someone who can solve the most questions experimentally, or else make the best compromise it can on the basis of inadequate data.

We do object to vague specifications such, for example, as the A. S. T. M. specification for high-speed tool steels, which gives a permissible range of variations in chemical composition, but leaves the base from which those variations may occur for mutual agreement between buyer and seller and, hence, really specifies nothing. The important problem of testing the performance of the steel is not at all touched upon, because no cheap and acceptable method has been devised. We fail to see that an attempt to use this specification puts the buyer in any better position than if he bought on brand, and to our mind, there is no excuse for a specification that does not specify anything at all as to quality or give any measure of quality. We should not pretend to specify materials which we cannot yet test or evaluate, for such specifications make specifications in general less highly regarded, and sometimes open to ridicule.

This is no reason for not making the best tentative specifications we can when we do know what to specify even if it is only partial. But there should be some way of designating how seriously we ought to take the precise figures of different items in a specification which stand on different bases. In specifications for brass ingot metal 85–5–5–5, we find the limit of 0.25% Sb. Just how much proof is there that 0.15% Sb is not harmful, or that 0.35% is? If references were made in footnotes to the specification to published experimental data which form the basis for each particular clause, or failing such data, to recorded opinions of authorities, the specification-user could form a better opinion as to whether he should insist on each limit to exactly the same degree.

A specification is not a piece of exact mathematics, it is a document based partly on precise experimental evidence, partly on human interpretation and human belief. The more completely the factor of belief can be replaced by facts, the better the specification. We have to use specifications based on belief, but such specifications are not as holy as some purchasing agents are inclined to think.

We object to so phrasing specifications that one cannot tell the facts from the beliefs, and we heartily applaud the activities of groups who are getting facts and putting them into specifications.

To the Editor of METALS & ALLOYS:

Dear Sir: The following comments are somewhat belated owing to the writer's absence in Europe at the time METALS & ALLOYS first appeared. Permit me, in the first place, to congratulate you on the successful launching of your journal, which, being devoted to the advancement of scientific metallurgy, will bring to metallurgists many matters of importance to them from other scientific fields apparently far removed, but often curiously connected.

Science is making such rapid strides nowadays, that it is often difficult to keep abreast of the latest developments, even in a journal article. I trust, therefore, that you will not take it amiss if I point out an error of commission and one of omission in the paper of Major Roger Taylor. In his article on "Stragetic Raw Materials," on page 7, he refers to the essential role of platinum as a catalyst in the manufacture of sulphuric acid, whereas the expensive Platinum is being replaced by Vanadium, which is not only cheaper by far, but is not "poisoned" by the usual Platinum poisons (Arsenic, Chlorine) and has a working efficiency at full load of 97 to over 98%. A little over a year ago, L. F. Nickell of Monsanto Chemical Company stated that within a decade all the Platinum would be supplanted by Vanadium catalyst, in the manufacture of sulphuric acid. If the knowledge is sufficiently spread, this desideratum should be brought about even sooner.

The error of omission is the failure to include Vanadium as one of the essential "alloy" metals. The extremely high efficiency of Vanadium makes the tonnage relatively small; but it is essential for the production of high-speed tool steel. Furthermore, very many processes and machines would have to be revamped or redesigned, with higher costs and diminished efficiency, if vanadium-containing alloys were not available. This includes locomotives, airplane and automobile engines, to mention but a few of importance in case of war.

JEROME ALEXANDER
Consulting Chemist and Chemical Engineer,
New York, N. Y.

To the Editor of METALS & ALLOYS:

Dear Sir: The writer would like to suggest that your able publication include articles covering the atmospheric corrosion of nonferrous metals and metallic coatings.

There seems to be a lack of information along such lines in the literature and text-books, and it seems that papers of such a nature should make a very favorable impression among your readers. It might be clear to you if we would state that we have looked for information regarding the corrosion of copper, aluminum, brass, chromium plating, nickel plating, etc., in atmospheres containing such acid vapors as sulphuric, nitric, hydrochloric and others, as well as sulphur dioxide and ammonia.

Recently, the writer was called upon to give such information, no time or facilities being available to make suitable tests. Practically all articles on corrosion resistance of various metals dealt with solutions to cover the side of atmosphere corrosion. Of course, it is quite evident that the relative humidity will be a factor in such tests, but even taking this into consideration, no specific information or data was uncovered in a fairly good search of the representative literature.

GARRETT B. JAMES

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Editor's Note: We shall be only too happy to publish articles of this nature, and hope anyone having data on such tests will submit the results for publication.

To the Editor of METALS & ALLOYS:

Dear Sir: By making the content of the numbers as they appear authoritative, you will never lack an audience, and even if only one important article a year appears which strikes right into a man's chosen field, his subscription will be renewed. But you must educate your readers to study other fields than their own as presented by you, and this by constantly showing the relation, or rather inter-relation, of as many fields as can be touched. Thus, the reader cannot afford to miss some point in the other articles he would otherwise not pay any attention to. Thus, in my own book on the "Principles of Iron Founding," I describe steelmaking processes, though discussing cast iron—also blast furnace practice. My foundry friends tell me that my discussion of these things as related to cast iron has shown them why they must avoid oxidation. Similarly my blast furnace friends tell me that they are glad to know the angle of the foundryman on pig iron and what he can reasonably expect.

When you bring out, say, a discussion of beryllium, such that I as a cast iron man cannot afford *not* to read it, you will have achieved something, and you need not worry about "METALS & ALLOYS" not paying promptly.

RICHARD MOLDENKE

Watchung, N. J.

A discussion of Leland Russell van Wert's paper, "The Effect of Lead on the (Alpha + Beta)/Beta Equilibrium in a 60/40 Brass (Muntz Metal)." Published in the November issue of METALS & ALLOYS, **1**, 200 (1929).

To the Editor of METALS & ALLOYS:

Dear Sir: In this paper Prof. van Wert classified the five alloys which he used in the conventional way, that is, only the copper contents were considered. For many purposes it is permissible to ignore one of the components of a ternary alloy but when quantitative estimates of phase changes are being made this procedure is liable to be misleading. For example, Table I in Prof. van Wert's paper has been rearranged in the following table to emphasize the zinc contents of the alloys:

Table A

Alloy	Zinc (by difference)	Lead	Iron	Tin	Copper
A	40.04%	0.04%	0.03%	Nil	Remainder
B	40.40%	0.33%	0.03%	Nil	Remainder
C	39.56%	0.85%	0.02%	Nil	Remainder
D	39.28%	1.05%	0.02%	Nil	Remainder
E	38.49%	1.76%	0.02%	Nil	Remainder

From the above it would appear that Alloy E is completely within the alpha field while Alloys C and D are just over the boundary in the alpha-beta field. These conclusions are quite at variance with those arrived at from a consideration of the copper contents and obviously are not correct. By the same token the classification of the alloys by their copper contents alone is equally misleading.

Since the title of the paper is "The Effect of Lead on the (Alpha + Beta)/Beta Equilibrium in a 60/40 Brass (Muntz Metal)" it would seem that Prof. van Wert intended to consider the effect of additions of lead to a binary 60/40 alloy. In the following table are listed the compositions of the binary copper-zinc alloys to which various additions of lead could be made to secure the ternary alloys listed in Table I:

Table B

Alloy	Copper	Zinc
A′	59.91%	40.09%
B′	59.44%	40.66%
C′	60.01%	39.99%
D′	60.28%	39.72%
E′	60.80%	39.20%

In other words, the addition of the proper amount of lead to, say, Alloy E′, will yield an alloy of composition E listed in Professor van Wert's paper. Therefore, it seems logical, when considering phase changes as shown in the *binary* copper-zinc diagram, to convert the ternary alloys to their binary equivalents listed above.

If Prof. van Wert's results are now carefully examined from this point of view it becomes apparent that his conclusions must be modified. On page 201, in the last sentence of the paragraph entitled "Series I" the author concludes that "the solubility of alpha in beta is decreased since those alloys of 0.33 percent lead and above have considerably more of the alpha phase than Alloy A with negligible lead." However if the *effective copper contents* given in Table A are considered it will be seen that all the alloys with the exception of B should be expected to show considerably more beta than Alloy A. Since Alloy E has an *effective copper content* nearly one percent higher than A, the relative amounts of alpha shown in photographs D and C, Fig. 3, are not at all improportionate. It is also not surprising that Alloy E heated to 800° C. shows considerable residual alpha since its *effective copper content* of 60.80 percent brings it well within the alpha-beta field at that temperature.

In the discussion of Series III, page 203, Prof. van Wert states that "Alloy E (see Photomicrograph 1, Fig. 3) shows, after one-half hour's heating at 75° C. above the normal solubility limit of the alpha solution, still an occasional crystallite of undissolved alpha." If the *effective copper content* is considered it will be seen that Alloy E is certainly not more than 0.3% within the beta field at 850° C. Therefore, if residual alpha is found in this alloy when heated to 850° C. (and this is not clearly shown in Photomicrograph 1, Fig. 3) it is not indisputable proof of the effect of lead on the solubility of alpha unless it is accepted that the alpha-beta/beta line in the copper-zinc equilibrium diagram is very accurately located at 850° C.

The conclusions reached with regard to the relative amounts of alpha found in Alloys A and E after the various heat treatments given in Series IV and V, must be modified if Alloy E is considered equivalent to a binary alloy of 60.80% copper. In fact, all of the microstructures shown are exactly as would be predicted from the unmodified equilibrium diagram.

If the four items of Prof. van Wert's Conclusions (page 205) are surveyed it is found that:

1. The higher temperatures are necessary for the complete solution of alpha on heating the leaded alloys only because the *effective copper contents* of those alloys are higher.
2. The increased difficulty of retaining the alpha in solid solution in the beta on rapid cooling is due to the fact that the higher *effective copper content* decreased the beta stability in a perfectly normal fashion.
3. The less stable condition of the supersaturated beta solution is similarly explained.
4. The larger amount of the alpha constituent in the slowly cooled alloys containing lead is likewise quite normal since the leaded alloys have a higher *effective copper content*.

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Melting, Mechanical Working and Some Physical Properties of Rhodium*

By Wm. H. Swanger†

Introduction

The work done in the past few years at the Bureau of Standards on methods for the purification of the platinum metals has made available very pure material for determining the properties of these metals and of their alloys. The present paper will outline the work which has been done on the melting, the mechanical working, and the physical properties of pure rhodium.

Although rhodium has been known since 1804 when it was discovered by Wollaston, its use has been limited almost entirely to the platinum-rhodium alloys for thermocouples, which contain 10 or 13 percent of rhodium. The lack of its application to other uses has been chiefly due to its scarcity. Crude platinum, its chief source of supply, contains only about 1 percent of rhodium. According to statistics of the Bureau of Mines[1] the stock of rhodium (plus ruthenium and osmium) in the hands of refiners at the end of the year 1927 was 4369 ounces compared to 88,000 ounces of platinum, and the imports of rhodium into the United States during the year were 1308 ounces compared to 128,000 ounces of platinum.

Aside from its scarcity, the difficulties in fabrication have probably kept pure rhodium from the list of industrially useful metals. Mention of specimens of mechanically worked rhodium occurs in a few places int he literature but no description is given as to the methods used, other than that the specimens were prepared only with great difficulty.

Preparation of Rhodium Sponge

The pure rhodium sponge used in the present work for the preparation of rods and wires of rhodium was prepared by the method described by Wichers, Gilchrist and Swanger.[2] Briefly, this process consisted of heating commercial or crude rhodium in finely divided form with sodium chloride in an atmosphere of chlorine gas, to a temperature of about 600° C. The partially fused mass of sodium rhodium chloride thus obtained was dissolved in water. This solution was then boiled with an excess of sodium nitrite, which converted the rhodium to the soluble sodium rhodium nitrite. A small amount of sodium sulphide was then added to remove lead as sulphide. Some of the platinum and palladium present was also precipitated, but not much of the rhodium. After filtration, a saturated solution of ammonium chloride was added to precipitate ammonium rhodium nitrite, $(NH_4)_3Rh(NO_2)_6$. This salt was easily decomposed by hydrochloric acid, yielding a solution of rhodium chloride. The foregoing process was then repeated as many times as necessary to produce a final product of the desired degree of purity.

As ammonium rhodium nitrite is not a suitable salt for reduction to sponge by ignition, it was converted to ammonium rhodium chloride. This salt was ignited in air and the somewhat oxidized sponge thus obtained was reduced in hydrogen.

Preparation of rhodium sponge made by this process has shown no impurities by spectrographic examination, except for traces of iridium in some instances. The melts described in the present paper were made from these preparations.

* Publication approved by the Director of the Bureau of Standards of the U. S. Department of Commerce.

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[1] "Platinum and Allied Metals in 1927," the *Jewelers Circular* **96**, No. 19, 55 (1928).

[2] E. Wichers, R. Gilchrist and Wm. H. Swanger, "Purification of the Six Platinum Metals," *Trans. A. I. M. E.*, **76**, 602–630 (1928).

Melting and Working of Rhodium

Melting in the Oxy-hydrogen Flame. The first melts of pure rhodium were made with a "hard" (oxygen rich) oxy-hydrogen flame, the rhodium being held on a block of hard-burned lime. It was found desirable to press the rhodium sponge into pellets in a steel mold before melting.

As soon as the rhodium melts in the oxy-hydrogen flame it begins to spit, small beads of metal are thrown off very rapidly, and when the melt freezes large excrescences form on the surface. This is presumably due to the evolution of gases which have been absorbed from the flame by the molten metal.

By sufficiently reducing the flow of oxygen to the melting torch this spitting of rhodium can be avoided to a considerable extent and the metal made to freeze with a fairly smooth surface. It is, of course, realized that a flame of this type, that is, a soft flame rich in hydrogen, may reduce lime at the temperature of molten rhodium and introduce calcium into the melt. However, by proper manipulation of the flame only the upper portion of the metal is melted at any one time, and the liquid metal can be kept out of contact with the lime while exposed to this soft flame. A button of rhodium melted in this manner can be lifted from the lime block cleanly with no adherence of lime to the metal.

Melting in the High Frequency Induction furnace. The melting of rhodium sponge in the high frequency induction furnace with access of air presents somewhat the same difficulties as does melting on lime with the oxy-hydrogen flame. The sponge must be compressed to a density sufficient to heat readily from the induced current. If the pellets are heated in air to a bright red and then allowed to cool to room temperature the sponge will be oxidized to such a degree that it cannot be heated readily in the high frequency furnace. By heating and cooling in hydrogen such oxidized rhodium sponge can be reduced to clean metal which will then heat easily in the induction coil.

Molten rhodium in an open crucible in the induction furnace spits badly and, if the furnace current is shut off suddenly so that the metal freezes rapidly, large blisters will grow out from the surface. By proper manipulation of the furnace current the metal can be frozen slowly so that a minimum of blistering occurs, and forgeable ingots are obtained.

The first melts in the induction furnace were made in zirconium oxide crucibles similar to those used at the Bureau for the melting of pure platinum.[3] However, it was found that this refractory softened at the temperatures sometimes attained in the molten rhodium. Nevertheless it broke away cleanly from the frozen metal and with care could be used for the melting of rhodium. One attempt to cast the molten rhodium into a graphite mold was unsuccessful as most of the metal was ejected from the mold by the rapid evolution of gas on sudden freezing.

A single melt of rhodium was made in an Acheson graphite crucible to confirm the reported solution of carbon by molten rhodium. There was no spitting or sprouting of the metal on freezing. The button was very hard and brittle and could not be forged either hot or cold. The increase in weight of the metal by melting in graphite was 1.8 percent. The color of the metal was noticeably darker than that of pure rhodium.

Thorium oxide crucibles were found the most satisfactory for

[3] L. Jordan, A. A. Peterson and L. H. Phelps, "Refractories for Melting Pure Metals: Iron, Nickel, Platinum," *Trans. Am. Electrochem. Soc.*, **50**, 163 (1926).

melting pure rhodium in the procedure finally adopted, that is, melting in vacuum in the high frequency induction furnace. For the preparation of these crucibles pure thorium oxide was fused in the electric arc in a stream of oxygen according to the method described by Fairchild and Peters.[4] The fused thoria was ground in a steel ball mill, using steel balls, and was then treated with hydrochloric acid to remove iron. The acid-washed fused oxide was mixed with a small amount of thorium chloride solution and this mixture was pressed or tamped in suitable molds designed to form a crucible with a wall thickness of about 3 mm. The molded crucibles were dried and then fired to 1700 to 1800° C. in an Arsem furnace. Care had to be taken in this firing to avoid direct contact between thoria and graphite at temperatures much above 1200° C. Thoria crucibles prepared in this manner are very dense and possess considerable strength. They have been used to melt platinum metal alloys at temperatures up to 2200° C.

The melting of rhodium in vacuum in the high frequency furnace will be described in more detail under the discussion of the melting point of rhodium. It is sufficient for the present to state that melts in vacuum were made in thoria crucibles at a pressure of 0.5 to 1.0 mm. of mercury. Rhodium melted under these conditions froze with a smooth surface of a silver-white color. Ingots of the maximum density reported for rhodium have been obtained in this way.

Forging and Swaging. The vacuum melts of rhodium weighed usually about 50 grams each. They were made in thoria crucibles measuring about 22 mm. in diameter at the top, 12 mm. at the bottom, and 30 mm. deep (all inside dimensions). These melts were allowed to freeze in the crucibles. The ingots were about 20 mm. long. The shrinkage cavity generally extended over so large a portion of the length of these small ingots that satisfactory forgings could not be made from them.

Several vacuum fused ingots broke up when forging was attempted. The crystals of these ingots were very large—up to 5 or 6 mm. across—and the fractures appeared to be intercrystalline. On the other hand, a number of ingots prepared in apparently the same way from the same lot of rhodium sponge and having just as large crystals were forgeable. It has not yet been found possible to control the forgeability of the vacuum fused metal.

Vacuum melted ingots remelted on lime with the oxy-hydrogen flame, however, always proved forgeable and this procedure was followed in preparing rods and wire. The forging or swaging of the remelted rhodium ingots did not present any unusual difficulties. These ingots could not be forged at room temperature, but became quite malleable above a red heat.

For the production of wire, the ingots were hand forged at about 1100° C. to bars of a shape and size (diameter of 10 mm.) suitable for swaging. The bars were heated in an oxy-gas or oxy-hydrogen flame and entered the swaging dies at about 1000° C. A rotary swager operating at 400 r. p. m. was used for bars from 10 mm. to 1.8 mm. in diameter. A smaller machine, operating at 600 r. p. m., was used for further swaging to 1.0 mm. Although dies were available for this machine to produce wire of 0.8 mm. diameter, it was found that the machine would not pass the wire through fast enough to prevent its cooling below the temperature at which it was malleable. Consequently, the hot swaging of rhodium wire of any considerable length was not carried to sizes below 1.0 mm.

A piece of 1-mm. wire about 35 feet long was prepared by hot swaging to be used as a winding for a resistance furnace in a study of certain reactions at temperatures higher than could be obtained in a platinum wound furnace. This wire was wound on a grooved alundum tube 1.5 inch in diameter with 6 turns per linear inch. It was heated to a red heat with a gas flame as it was wound on the tube. The furnace has been kept at a temperature of 1875° C. for 4 hours although it is not intended to be used regularly at temperatures quite this high.

At the present time data are not available on the rate of deterioration of rhodium wire due to volatilization when used at high temperatures. When rhodium is heated to relatively low temperatures in air it becomes covered with an oxide film which disappears when the temperature reaches about 1200° C. If it is quenched in water or dilute hydrochloric acid from above this temperature it remains bright with a silvery white luster.

Drawing of Rhodium Wire. The rhodium wire produced by swaging at 800° C. or over was not ductile at room temperature. It could not be straightened out from a sharp bend without fracturing, nor reduced in diameter by cold drawing. The fracture appeared coarsely crystalline. The end of a piece of such wire could be flattened on an anvil to half its thickness by one sharp blow with a hammer, but fractured when the same thing was attempted with several light blows.

It was thought that if a fibrous structure could be imparted to the hot swaged wire it might become ductile. In view of the results obtained in the hot drawing of rhodium this probably could be accomplished during swaging by gradually lowering the temperature of the wire as it is passed through the successively smaller dies until finally it might be swaged at a temperature considerably below a red heat or cold drawn at room temperature. However, there was not enough material available for much experimental work along this line.

Recently, through the courtesy of Dr. S. L. Hoyt of the General Electric Research Laboratory, a set of tungsten carbide wire drawing dies, covering the range 0.41 inch to 0.020 inch, was made available to the Bureau. These dies can be used at a red heat. A piece of wire which had been hot swaged to a diameter of 1 mm. was successfully drawn through this series of dies to approximately 0.5 mm. (0.020 inch) in diameter. The dies were kept at about 600° C. by means of a gas burner. The wire was heated somewhat hotter (600–800° C.) as it passed through the die for the first three or four steps in reduction, but the temperature of the wire was gradually lowered until, for the last three or four dies, the wire was well below a red heat. The wire was lubricated by dipping it into a suspension of fine graphite in oil before each pass through the die. After this "hot drawing" operation the wire, now 0.020 inch in diameter, was drawn through a set of jewel dies at room temperature, without any annealing, to 0.0144 inch. The resulting wire was ductile and could be bent sharply and straightened, coiled on a 1/8-inch rod, and twisted tightly upon itself without breaking, all at room temperature. It is quite probable that drawing at room temperature could be continued to wire of still smaller size. It is thus demonstrated that rhodium which has heretofore generally been reported as unworkable can be made ductile.

The microstructure of a longitudinal section of wire swaged to 0.040 inch diameter at a temperature above 800° C. is shown in Fig. 1. The microstructure of a longitudinal section of a piece of the swaged wire after it was drawn to 0.014 inch diameter, as described in the preceding paragraph, is shown in Fig. 2.

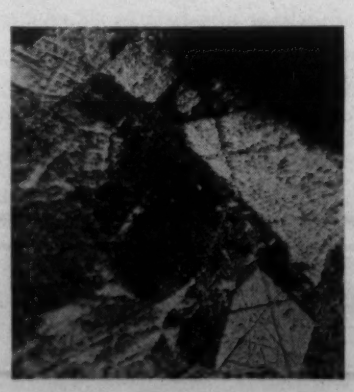

Fig. 1—Rh. Wire Swaged to 0.040 Inch Diam. at a Temperature above 800° C. × 100 Etched with Fused $KHSO_4$. (1/2 Reduction.)

Fig. 2—Rh. Wire Drawn from 0.040 Inch to 0.020 Inch Diam. at Temperatures between 700° C. and 400° C. and from 0.020 Inch to 0.014 Inch Diam. at Room Temperature. × 100. Etched with Fused $KHSO_4$. (1/2 Reduction.)

Photomicrographs by R. W. Buzzard of the Division of Metallurgy.

[4] C. O. Fairchild and M. F. Peters, U. S. Patent No. 1,545,951, July 14, 1925

The change from the relatively coarse-grained equiaxed structure of the swaged wire to the distinctly fibrous structure of the ductile wire is clearly seen.

The Melting Point of Rhodium. One of the most useful applications of rhodium wire appeared to be for windings for high temperature furnaces or heaters. Rhodium has a melting point considerably higher than platinum and like platinum does not readily oxidize or volatilize in air at high temperatures. In this connection it seemed advisable to redetermine the melting point of rhodium. The figures generally given in the literature for the melting point of rhodium, namely 1950 or 1955° C., were based on determinations made on metal which was probably not of the highest purity.

With the collaboration of Messrs. H. T. Wensel, W. F. Roeser and F. R. Caldwell of the Pyrometry Section of the Bureau a number of determinations of the melting point of rhodium were made. An Ajax-Northrup high frequency induction furnace was used for melting the rhodium. The arrangement is shown in Fig. 3. The metal was melted in a thoria crucible, A, within a closed end fused silica tube, D, which was evacuated. For heat insulation, ignited, but not fused, powdered thorium oxide, C, was packed about the crucible. An alundum extraction thimble, B, was used to hold the heat insulation and crucible inside the silica tube. The top of the silica tube was closed with the clear fused silica cover plate, E, whose absorption correction had been determined. The melting was carried out at pressures below 1 mm. of mercury, with a liquid air trap between the mechanical vacuum pump and the melting chamber. Temperature measurements were made with a Leeds and Northrup optical pyrometer sighted into a 2-mm. hole drilled in the ingot to a depth of 10 to 15 mm.

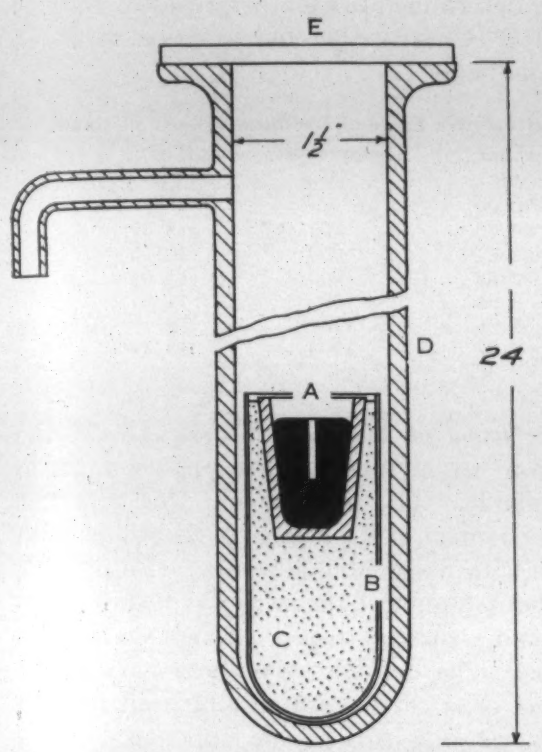

Fig. 3—Vacuum Furnace Assembly for Melting Rhodium by High Frequency Induction

The pyrometer was calibrated in the Bureau's Pyrometry Section and, in addition, was checked at the gold point and at the melting point of platinum using the same high frequency furnance set-up that was used for determining the melting point of rhodium.

The temperatures corresponding to the melting points were determined both by plotting the time-temperature heating curve C, and by observing the temperature at which the hole in the ingot filled with liquid metal. The flat portion of the heating curve for each melt extended over a period of at least 2 minutes during which time about 10 readings were taken. In all satisfactory experiments the last temperature reading obtained before the hole in the ingot filled was the same as the temperature corresponding to the flat portion of the heating curve. In some cases the sight hole had not been drilled deep enough into the ingot and the reflection of the cold top portion of the evacuated tube from the bottom of the hole appeared as a dark spot in the center of the image of the hole. This caused an error in that the values obtained for the brightness in the hole were obviously too low. The ratio of the depth of the sight hole to the diameter should be at least 8 to 1.

Cooling curves could not be taken as satisfactorily as heating curves. In all cases, however, it was possible to obtain two or three constant readings on the liquid surface of the melt while solid metal was spreading over the surface from the sides of the crucible. The correction necessary to convert the apparent temperature obtained by sighting on the freezing liquid surface of rhodium to true temperature was approximated by comparing the brightness in the hole and on the solid surface of several rhodium ingots just below the melting point. The difference in brightness thus obtained was used for correcting the apparent temperature of the liquid surface at the freezing point. This correction is somewhat too large since the emissivity of liquid rhodium has been found to be slightly higher than that of solid rhodium, and consequently the values obtained for the freezing point are presumably somewhat higher than the true value.

On two separate ingots, with the best black body conditions in the sight holes, the values for the melting point were 1986 and 1987° C., respectively. The values for the freezing points from the same two experiments were 2006 and 2002° C., respectively.

Another series of observations was made[5] on a third ingot, using a precision optical pyrometer[6] to make the temperature measurements. An arrangement of furnace, evacuated tube, and crucible similar to that described above was used, except that a "black body" was obtained somewhat differently. Instead of drilling a hole in the ingot and sighting on the bottom of that, a cover (of thorium oxide) was cemented on the crucible. To the bottom of this cover was fixed a thin-walled thorium oxide tube, about 2 mm. inside diameter, and closed at the lower end. The tube projected down through the center of the ingot to the bottom of the crucible. Temperature readings were made by sighting through a hole in the cover into the re-entrant tube, into which enough loose thorium oxide had been poured to fill it about one-third of the way from the bottom. This gave a "black body" into which to sight which was about two-thirds of the distance from the top of the ingot to the bottom. It is considered that the temperature measured inside the tube is that of the metal. The metal can thus be melted and frozen a number of times without disturbing the crucible or contents as long as the sight tube remains intact. On plotting the time-temperature curves for determinations made with this type of crucible there was a flat region on each curve extending over a period of about 5 minutes. Observations were made on 3 melts and 5 freezes. The temperatures corresponding to the flat portions of the curves were as follows:

Melting	Freezing
1985° C.	1984° C.
1984° C.	1985° C.
1984° C.	1983° C.
	1986° C.
	1983° C.
Av. 1984° C.	Av. 1984° C.

These values show the precision to which the brightness at the melting and freezing points of rhodium can be determined, but does not necessarily mean that the conversion of these measures of brightness to degrees Centigrade was as accurate as the agreement between the separate determinations. Up to the present time, accurate checking of the factors entering into this conversion have not been made. The temperatures given above are certainly accurate to within plus or minus 10 degrees. The Pyrometry Section of the Bureau, within whose province the accurate determinations of melting points come, is planning to make a more precise determination of the melting point of rhodium in the near future, and the uncertainty of the temperature conversion will then be much less than 10 degrees Centigrade.

From the results of the two methods described, the melting point of rhodium is given, tentatively as 1985° C. ± 10°.

Most of the tables of physical constants of the elements give the melting point of rhodium as 1950 or 1955° C. Mendenhall

[5] Observations by H. T. Wensel, W. F Roeser and F. R. Caldwell.

[6] C. O. Fairchild, W. H. Hoover and M. F. Peters, "A New Determination of the Melting Point of Palladium," *B. S. Jour. Research*, **2** (R. P. 65), May, 1929.

and Ingersoll[7] determined the melting point of rhodium based on the melting points of gold as 1065° C. and of platinum as either 1745 or 1789° C. Their value was 1907° C. (Pt = 1745° C.) or 1968° C. (Pt = 1789° C.). von Wartenberg[8] reported his own determination of the melting point of rhodium as 1940° C. based on C_2 = 1.460 cm. degrees and recalculated a previous determination by Holborn and Henning to 1946° C. These two values become approximately 1970 and 1975° C., respectively, on the International Temperature Scale which is based on the value 1.432 cm. degrees for C_2.[9]

Other Physical Properties of Rhodium. In the course of the experiments on the melting and working of rhodium, as suitable specimens became available for the determination of physical constants they were submitted to the laboratories of the Bureau most directly concerned with the particular measurements required.

New determinations of the following physical constants were made by the members of the Bureau staff named below: density by Miss E. E. Hill; X-ray lattice constant by E. C. Groesbeck; electrical resistivity by A. R. Lindberg; thermal electromotive force and temperature coefficient of resistance by F. R. Caldwell; thermal expansion by W. T. Creoney; and reflecting power by W. W. Coblentz and R. Stair. Grateful acknowledgment is made for this assistance in obtaining new data on the properties of rhodium. A number of hardness determinations made by the author are also included.

A short description of the above determinations follows:

1. Density.—Previous determinations of the density of rhodium reported in the literature range from 11.0, the value given by Wollaston in 1804, to 12.6 (g./cm.^{3}). Holborn, Austin and Henning[10] found a value of 12.44 for rhodium foil prepared by Heraeus. The most recent determinations are by Rose.[11] He found 12.22 for the density of an ingot which was forged from sponge but not melted. The density of another ingot, melted and forged, was 12.47. In reviewing previous determinations Rose calculated that the value 12.6 given by Mylius and Dietz[12] would become 12.51 when corrected for the impurities, chiefly iridium, which the rhodium contained. He further states that the density of pure rhodium, melted and forged, might be provisionally taken as 12.5.

In the present work the density of three rhodium ingots after melting in vacuum was 12.42, 12.41 and 12.41 g./cm.^{3}, respectively. The three ingots were then melted together on a block of lime with an oxy-hydrogen flame. The button was hot forged and then hot swaged to a rod 7 inches long by 0.265 inch in diameter. The density of this rod was 12.40 g./cm.^{3} The rod was subsequently hot swaged to 0.040 inch wire. The density of the wire was also 12.40 g./cm.^{3}

2. X-ray Diffraction Data.—The crystal lattice of rhodium is face centered cubic. Hull[13] determined the length of the side of the unit cube, to be 3.82 Ångstroms. Barth and Lunde[14] have more recently given a_o = 3.794 Å. If a_o is taken as 3.82 the calculated density of rhodium is 12.16 which is quite certainly lower than the true density. The calculated density becomes 12.43 if a_o = 3.794, a value nearer to the observed density.

Two determinations of the length of the side of the unit cube made on the rhodium sponge used in the present work gave:

1st determination—a_o = 3.773 ± 0.0025Å.
2nd determination—a_o = 3.774 ± 0.002 Å.

The density calculated from these values is 12.6, which is somewhat higher than the observed density. However, it is generally agreed that the density calculated from the value for the lattice constant is always higher than the density obtained by direct determination.

3. Electrical Resistivity.—The resistivity of pure rhodium as determined on wire hot swaged to a diameter of 1 mm. and annealed at a temperature well over 1200° C. was 4.93 microhm-centimeters at 20° C.

The value given in the International Critical Tables is 5.1 at 20° C. In Carter's[15] tabulation of the physical properties of rhodium the resistivity at 0° C. is given as 5.11.

4. Thermal Electromotive Force.—The thermal electromotive force of rhodium against the Bureau's purest platinum (Pt Standard No. 27) was determined for temperatures of the hot junction from 0 to 1100° C. with the cold junction at 0° C. The results are given in Table 1.

Table 1—Thermal Electromotive Force of Rhodium against Platinum

Temperature, ° C.	E.m.f., mv.	Temperature, ° C.	E.m.f., mv.
0	0.00		
100	0.70	700	8.40
200	1.61	800	10.16
300	2.68	900	12.04
400	3.92	1000	14.05
500	5.28	1100	16.18
600	6.77	1200	18.42[1]

[1] Extrapolated.

5. Temperature Coefficient of Electrical Resistance.—At the time this determination was made wire less than 1 mm. in diameter was not available. The resistance of this wire was too low to make a measurement of the change of resistance with change of temperature with reasonable accuracy. To provide a suitable specimen about 1 mm. of the wire was clamped between electrical leads and a current passed through the wire to heat it to dull redness. The hot wire was passed back and forth between the rolls of a small hand rolling mill until a ribbon 0.007 inch thick was obtained. This ribbon was fairly ductile. The resistance was measured at 0 and at 100° C. The average temperature coefficient of resistance between these temperatures was 0.00436. Holborn[16] reported a value of 0.00443. Additional determinations of this important physical constant will be made.

6. Thermal Expansion.—The linear coefficient of thermal expansion of rhodium was determined by the interferometric method. The values given in Table 2 are considered accurate to within one percent.

Table 2—Thermal Expansion of Rhodium

Temperature Range	Average Coefficient of Expansion per Degree Centigrade
20 to 50° C.	8.1×10^{-6}
20 to 100	8.3
20 to 200	8.5
20 to 300	8.9
20 to 400	9.3
20 to 500	9.6

The International Critical Tables give the coefficient of thermal expansion as 8.4×10^{-6} at 20° C. Carter, in his tabulation of the physical properties of the platinum metals, gives 8.4×10^{-6} at 20° C. and 8.5×10^{-6} at 40° C.

7. Reflecting Power.—A determination was made of the reflecting power of rhodium in the visible and in the ultra-violet spectrum to wave-length 250 mμ. The surface of the ingot that was used did not have a good polish and diffused considerable radiation. Instead of having a reflecting power of 78% in the visible spectrum as previously determined by Coblentz[17] it was only about 45%. However, the reflecting power was

[7] C. E. Mendenhall and L. R. Ingersoll, "The Melting Points of Rhodium and Iridium," *Phys. Rev.*, **25**, 1–16 (1907).

[8] H. von Wartenberg, "Über optische Temperaturmessung blanker Körper, "*Verhandl. deut. physik. Ges.*, **12**, 121–127 (1910).

[9] "C_2" is the constant in Wien's radiation law which, together with the value of 1063° C. for the melting point of gold, defines the high temperature scale.

[10] L. Holborn, L. Austin and F. Henning, "Die Zerstäubung und Recristallisation Elektrisch Geglühter Platinmetalle," *Wiss. ab. Phys. Tech. Reichsanstalt*, **4**, 87 (1903).

[11] Sir Thomas Kirke Rose, "On the Density of Rhodium," *Jour. Inst. Metals*, **33**, No. 1, 109–110 (1925).

[12] F. Mylius and R. Dietz, "Reine Platin-Metalle im Handel," *Ber.*, **31**, 3189 (1899).

[13] A. W. Hull, "X-Ray Crystal Analysis of Thirteen Common Metals," *Phys. Rev.*, **17**, 571–588 (1921).

[14] T. Barth and G. Lunde, "Der Einfluss der Lanthanidenkontraction usw.," *Zeit. Phys. Chem.*, **117**, 478–490 (1925).

[15] F. E. Carter, "The Platinum Metals and Their Alloys," *A. I. M. E., Proc. Inst. Metals Div.*, **1928**, page 759.

[16] L. Holborn, "Uber die Abhangig Keit des Widerstandes reiner Metalle von der Temperature," *Ann. d. Physik.* (4), **59**, 145 (1919).

[17] W. W. Coblentz, "The Reflecting Power of Various Metals," *B. S. Sci. Paper*, No. **152**.

fairly constant across the visible spectrum but dropped off rapidly in the ultra-violet until at 250 mμ it was about two-thirds of the value in the visible spectrum.

8. Hardness.—Hardness determinations were made on several specimens of the melted and forged rhodium. The shape of the specimens as melted made it impracticable to make hardness determinations without forging although a Brinell number was obtained on the ingot as melted. The hot forged specimens were annealed at a temperature well over 1200° C. The following values were obtained:

Table 3—Hardness of Rhodium

	Specimen A, Melted but not Forged	Specimen B, Melted but Forged	Specimen C, Melted but Forged
Baby Brinell 12.8 kg., 1/16" ball	101	101	...
Rockwell "E" 100 kg., 1/8" ball	...	90	85
Scleroscope	...	12	10
Vickers Hardness Tester; 136° diamond pyramid 10 kg.	...	121	125
Herbert Pendulum (Time Hardness)	...	16.4	15

Carter[18] has given the Baby Brinell hardness of cast rhodium as 139.

The hardness values obtained in the present work correspond quite closely with those of hard rolled copper. Despite this apparent softness, rhodium does not machine readily. Great difficulty was experienced in drilling the sight holes in the specimens used for melting point determinations. An ordinary twist drill made hardly any impression. Flat drills made of carbon-steel drill rod quenched from a bright red heat in ordinary zinc chloride soldering flux seemed to give the best results.

Acknowledgment

Grateful acknowledgment is made to Louis Jordan of the Metallurgy Division whose aid and advice contributed materially to the accomplishment of the work reported in this paper.

[18] *Loc. cit.*

Light Alloys[1]

By Zay Jeffries[2]

Light weight alloys having aluminum as their principal constituent occupy not only a definite but a prominent place in industry. Alloys in which magnesium is the principal constituent have gained such recognition by industry in recent years that they may now be considered among the standard engineering materials. Although beryllium has been produced in small quantities during the past few years and its preparation may be considered as a welcome metallurgical achievement, its light alloys have not as yet gained sufficient headway in industry to warrant further mention in this paper. Also calcium can be readily produced, but so far no way has been found to sufficiently retard its rate of oxidation in ordinary atmosphere to render it suitable for structural purposes.

Aluminum Alloys

Technically so-called "commercially pure" aluminum is an alloy because it always contains iron and silicon and sometimes in addition either copper or titanium or both. Although these "impurities" were unavoidable, until the Aluminum Company of America produced aluminum of 99.98 percent purity, they are now known to affect definitely, and in certain respects substantially, the properties of pure aluminum, and their presence is in many cases very beneficial. Copper, silicon, magnesium, manganese, zinc, iron, nickel and tin are the principal metals added to aluminum in the preparation of commercial alloys. Thousands of combinations of these and other elements with aluminum have been tried and many are in commercial use. The list given in Table I is representative of compositions comprising over 90 percent of the tonnage of commercial alloys.

A number of aluminum alloys are in commercial use which vary only slightly in composition from those given in Table I. In general, the composition adopted for any particular use is a compromise between physical properties, fabricating characteristics and cost, and the selection is often so involved as to require careful engineering consideration by both consumer and producer.

Aluminum alloys are used extensively in both the wrought and cast forms. Wrought products include sheet, strip, rod, bar, wire, tubing, forgings and extruded and rolled shapes. Sand, permanent mold, semi-permanent mold and pressure die castings are all produced in substantial quantities.

In England there has been a tendency to call any casting made in an iron or steel mold a "die casting" whether or not pressure has been used. There is not only a marked difference in process but also in product between the gravity or low pressure and the high pressure methods. In America the former is referred to as the "permanent mold" process when all metal molds are used and the "semi-permanent mold" process when sand cords are used in conjunction with metal molds. The term "die casting" implies the use of high pressure. Permanent and semi-permanent molds are so gated and filled as to avoid entrapped air and to compensate for crystallization shrinkage so the castings are substantially free from porosity. The metal molds not only permit manufacture more nearly to size than sand molds but the chilling effect results in a marked improvement in certain properties. Although die castings are more or less porous as a result of the very rapid filling, they have a strong, highly chilled surface, and may be made in thinner sections than any other type and with such precision of dimensions as to require little or no machining.

Mechanical working affords not only a convenient and economical method of producing certain desired shapes, but also profoundly affects certain properties.

Some of the cast and wrought alloys may have certain of their properties changed within wide limits by heat treatment. In addition to the familiar annealing treatment to soften cold worked metal, other heat treatments are used on a large commercial scale. Duralumin, for example, after mechanical working, is heated for a short time at about 500° C. and cooled rapidly. If tested immediately after cooling, it may have a strength of 45,000 lb./in.^{2} It strengthens and hardens at room temperature to such an extent that four days after the heat treatment it may have a strength of 60,000 lb./in.^{2} The first thermal treatment is now referred to as the "solution heat treatment" because the purpose is usually to get as much alloy as possible in solid solution in the aluminum. The rapid cooling is designed to retain the alloy in solid solution at lower temperatures.

The breakdown of the super-saturated solution at room temperature is supposed to be the cause of the age-hardening of

[1] A paper delivered at the World Engineering Congress, Tokio, Japan, Oct. 29 to Nov. 7, 1929.

[2] Consulting Engineer, Aluminum Company of America.

duralumin. A very large number of submicroscopic particles of a hard compound are supposed to be precipitated from the solid solution. A heat treatment designed to control this precipitation as regards rate, degree or extent, is called a "precipitation heat treatment." Duralumin attains its full strength by room temperature aging but some alloys require treatments at higher temperatures to produce optimum properties. There are many variations and combinations of heat treatments applied to aluminum alloys at the present time and the art is only in its infancy.

TABLE I—COMMERCIAL ALUMINUM ALLOYS

Alloy: Arbitrary Designation	Alloy: Commercial Designations	Approximate Chemical Composition not Including Aluminum or Impurities: Cu	Si	Mg	Fe	Mn	Zn	Ni	Sn	Usual Commercial Form
A	No. 195	4								Heat-treated castings
B	S. A. E. 30; No. 12	8								Castings
C	S. A. E. 33; No. 112	7.5			1.2		1.5			Castings
D	S. A. E. 32; British L8; No. 109	12								Castings
E	S. A. E. 34; No. 122	10		0.25	1.2					Cast pistons
F	S. A. E. 35; No. 43		5							Castings
G	Alpax; Silumin; No. 47		13							"Modified" castings
H	No. 13		12		2					Pressure die castings
I	No. 108	4.5	5.5							Castings
J		8	2							Castings
K	No. 145	2.5			1.2		10			Castings
L	British L5	2.5					13.5			Castings
M	No. 106					2				Castings
N		7							1	Castings
O	No. 134	4	13							Permanent mold castings
P	No. 132	1	14	1					2	Permanent mold castings
Q	No. 73	2.5	8.5							Pressure die castings
R	No. 83	2.5	3							Pressure die castings
S	No. 85	3.5	5.5							Pressure die castings
T	No. 93	4	2					4		Pressure die castings
U	3S					1.25				Wrought
V	Duralumin, Dural, 17S	4		0.5		0.5				Wrought and heat treated
W	25S, Lautal, Aeron	4.5	0.75			0.75				Wrought and heat treated
X	51S, Aludur		1	0.8						Wrought and heat treated
Y	No. 142, Y Alloy	4		1.5				2		Wrought and heat-treated and castings

TABLE II—TENSILE PROPERTIES AND HARDNESS OF SAND CAST ALUMINUM ALLOYS

Alloy: Designation from Table I	Condition	Tensile Properties: Tensile Strength in Pounds per Square Inch	Percent Elongation in 2 Inches	Approximate Yield Point in Pounds per Square Inch	Approximate Brinell Hardness Number
B	As cast	18,000 to 23,000	1 to 3	10,000	65
C	As cast	19,000 to 24,000	1 to 2.5	11,000	65
D	As cast	20,000 to 28,000	0 to 1.5	15,000	70
F	As cast	17,000 to 22,000	3 to 7	7,000	40
G	Modified	24,000 to 31,000	5 to 15	9,000	50
A	Single heat treatment	28,000 to 38,000	6 to 12	13,500	65
A	Double heat treatment	30,000 to 50,000	0 to 8	21,000 to 27,000	75 to 100
K	As cast	25,000 to 37,000	3 to 6	12,000	65
E	Heat treated	35,000 to 40,000	0 to 1	20,000	115
Y	Heat treated	30,000 to 40,000	0.5 to 2	25,000	100

The wide ranges attainable in tensile properties and hardness of aluminum alloys by the use of different alloy compositions, the use of different methods of fabrication, and the application of various heat treatments may be seen by referring to Tables II, III, IV and V.

TABLE III—TENSILE PROPERTIES AND HARDNESS OF ONE-HALF-INCH DIAMETER TEST BARS CAST IN AN IRON MOLD (PERMANENT MOLD)

Alloy: Designation from Table I	Condition	Tensile Properties: Tensile Strength in Pounds per Square Inch	Percent Elongation in 2 Inches	Brinell Hardness Number
C	As cast	21,000 to 29,000	1.5 to 3	70 to 90
F	As cast	18,500 to 24,500	3 to 8	40 to 45
I	As cast	21,000 to 29,500	1 to 4.5	65 to 80
A	As cast	22,000 to 28,000	3.0 to 6.0	60 to 70
A	Single heat treatment	35,000 to 39,000	5 to 9	70 to 90
A	Double heat treatment	48,000 to 54,000	1 to 1.5	110 to 140
E	As cast	22,000 to 30,000	0 to 1.5	85 to 105
E	Heat treated	24,000 to 48,000	0 to 2	70 to 160

TABLE IV—TENSILE PROPERTIES AND HARDNESS OF PRESSURE DIE CAST TEST BARS

Alloy: Designation from Table I	Remarks	Tensile Properties: Average Tensile Strength in Pounds per Square Inch	Average Percent Elongation in 2 Inches	Brinell Hardness Number
H	All tensile properties were	34,000	2.25	80
Q	made on a 1/4-inch round	30,000	2.0	80
R	bar tested without machining	29,000	4.5	60
S	Hardness measurements	34,000	3.5	75
T	were made on flat bars 1/8-inch thick	33,000	1.5	83

TABLE V—TENSILE PROPERTIES AND HARDNESS OF WROUGHT ALUMINUM ALLOYS

Alloy: Designation from Table I	Condition	Tensile Properties: Tensile Strength in Pounds per Square Inch	Yield Point in Pounds per Square Inch	Percent Elongation in 2 Inches	Brinell Hardness Number
U	Annealed	14,000 to 17,000	4,500 to 5,500	30 to 40	25 to 30
U	Cold worked "half hard"	24,000 to 28,000	20,000 to 26,000	4 to 15	43 to 48
U	Cold worked "hard"	30,000 to 35,000	25,000 to 30,000	3 to 10	52 to 57
X	Annealed	14,000 to 19,000	4,000 to 6,000	15 to 30	25 to 32
X	Quenched and aged at room temperature	30,000 to 40,000	15,000 to 20,000	20 to 30	55 to 70
X	Quenched and aged above room temperature	45,000 to 50,000	30,000 to 40,000	10 to 18	90 to 100
V	Annealed	25,000 to 35,000	7,000 to 10,000	14 to 22	45 to 55
V	Quenched and aged at room temperature	55,000 to 63,000	30,000 to 40,000	18 to 25	90 to 105
W	Annealed	23,000 to 35,000	7,000 to 12,000	12 to 20	45 to 55
W	Quenched	45,000 to 53,000	15,000 to 30,000	15 to 22	68 to 85
W	Quenched and aged above room temperature	55,000 to 63,000	30,000 to 40,000	16 to 25	90 to 105

While the engineer may be interested principally in the tensile properties and hardness of aluminum alloys, certain other properties are of prime importance for specific uses. It is not possible to enter into any detailed discussion of these properties in the present paper but a résumé suggesting the high and low limits may prove helpful.

1. *Specific Gravity.*—Wrought aluminum of 99.95% purity has a specific gravity of 2.70. The specific gravities of the alloys can be calculated by the rule of mixtures with sufficient accuracy for ordinary purposes. The 13% silicon alloy is the lightest of the commercial alloys with a specific gravity of 2.64, and the heaviest is the high zinc alloy with a specific gravity of about 3.0.

2. *Young's Modulus of Elasticity.*—(E) Young's Modulus of aluminum and most of its alloy is about 10,000,000 lb./in.^{2}

3. *Thermal Expansivity.*—The average coefficient of thermal expansion of aluminum between 20 and 100° C. is about 0.000024 per degree C. The value for the aluminum-copper alloys used generally for automobile and aircraft engine pistons is about 0.000022 per degree C. Some alloys high in silicon having a value of 0.000019 per degree C. or lower, permit the use of relatively small clearances in piston fitting.

4. Electrical Conductivity.—For equal sections, commercial aluminum of conductor grade has an electrical conductivity about 61% that of copper. The conductivities of the aluminum alloys in common use vary from about 30 to 55% of the copper value. If higher electrical resistivity is desired, it can be obtained by the use of special alloys.

5. Thermal Conductivity.—The thermal conductivity of aluminum at 100° C. in C. G. S. units is about 0.51. The values for the alloys in common use vary from about 0.25 to 0.48.

6. Resistance to Repeated Stresses.—The endurance limits of wrought aluminum alloys measured on the rotating beam type of machine vary from ±6000 to ±15,000 lb./in.^{2}; 500,000,000 cycles are considered sufficient to determine the endurance limit. The higher values are obtained in the heat-treated alloys of the dural type. Values for cast alloys vary from ±5500 to ±10,000 lb./in.^{2}

7. Behavior at Low Temperatures.—The tensile strength and elongation of wrought aluminum alloys, in general, increase with decrease of temperature, even to the temperature of liquid air (−190° C.). The tensile strength of cast alloys increases also with decrease of temperature. Extensive use of both wrought and cast aluminum alloys in aircraft, in some instances under conditions of severe cold, indicates no difficulties from lack of low temperature toughness.

8. Behavior at Elevated Temperatures.—The tensile properties of certain wrought aluminum alloys at elevated temperatures are shown in Table VI. Table VII gives the high temperature properties of some cast alloys

9. Resistance to Corrosion.—Aluminum and many of its alloys are highly resistant to ordinary atmospheric corrosion. The alloys, however, are attacked slowly by salt water or a salt water spray. This attack is often not sufficient to be serious in the thicker sections usually obtained in castings and forgings but may be very serious in thin sheet. The highly resistant qualities of nearly pure aluminum may be used to protect an alloy of high strength against salt water in spray corrosion. The United States Bureau of Standards has used a coating of nearly pure aluminum sprayed onto the surface of strong alloy sheet. The Aluminum Company of America has succeeded in producing a composite sheet called "Alclad" sheet consisting of a heat treated strong alloy coated with nearly pure aluminum. The latter is welded to the strong alloy and the composite sheet can be mechanically worked without loss of adherence of the coating.

Alclad sheet, even when quite thin, is nearly immune to salt water spray corrosion. A remarkable fact is that the strong alloy exposed at a hole or edge is also practically immune from attack because of electrolytic protection by the coating which has the higher solution potential.

In general, aluminum and its alloys are attacked by alkaline solutions with the exception of ammonia. The action of weak alkalies such as carbonates and soaps may be retarded or even entirely prevented by the presence of small quantities of sodium

TABLE VI—TENSILE PROPERTIES OF WROUGHT ALUMINUM AND ALUMINUM ALLOYS AT ELEVATED TEMPERATURES

(R. L. Templin in laboratories of Aluminum Company of America)

Designation from Table I	Condition	Property	Temperature—Degrees Centigrade 24	93	149	205	260	316	371	427
U	Annealed	T. S.[1]	15,500	12,700	10,400	7,900	5,700	4,100	2900	2200
		Y. P.[2]	5,200	4,800	4,300	3,700	3,400	2,600	2100	1600
		Elong.[3]	37.0	42.0	47.0	53.0	59.0	61.0	58.0	53.0
		Red.[4]	77.0	81.0	84.0	87.0	90.0	91.0	90.0	89.0
X	Heat treated	T. S.	51,300	44,500	38,900	32,100	20,500	12,000	2600	1600
		Y. P.	40,000	34,500	30,000	24,000	15,500	7,500	1500	....
		Elong.	18.3	21.0	18.3	10.3	11.8	16.2	72.9	94.5
		Red.	32.3	42.2	35.8	23.2	32.0	43.0	96.5	97.7
W	Heat treated	T. S.	58,400	51,400	43,600	29,000	17,900	8,800	4500	3000
		Y. P.	40,000	33,500	29,500	22,300	13,300	7,300	3500	2000
		Elong.	19.6	19.8	20.5	22.3	23.8	33.0	54.8	72.0
		Red.	34.6	40.4	45.9	65.9	76.2	83.1	89.5	84.9
V	Heat treated	T. S.	58,000	52,500	43,900	38,900	21,000	10,000	5740	3900
		Y. P.	31,700	30,300	28,300	27,200	14,400	7,700	4100	2300
		Elong.	21.2	22.0	24.0	25.0	26.5	42.5	60.0	72.0
		Red.	35.7	34.7	41.0	44.1	68.2	82.1	89.0	78.9

[1] Tensile strength in pounds per square inch.
[2] Yield point in pounds per square inch.
[3] Elongation, percent in two inches.
[4] Reduction of area in percent.

TABLE VII—TENSILE PROPERTIES OF CAST ALUMINUM ALLOYS AT ELEVATED TEMPERATURES

(Templin, Braglio and Marsh)

Alloy—Designation from Table I	Condition	Property	Temperature—Degrees Centigrade 24	93	149	205	260	316	371	427
F	Sand cast	T. S.[1]	19,000	17,000	14,600	11,400	8,400	6,100	4200	2500
		Y. P.[2]	11,000	9,000	7,000	6,250	5,000	4,000	2500	1000
		Elong.[3]	4.75	9.00	12.2	15.6	2.12	23.9	26.6	32.2
		Red.[4]	4.20	10.5	15.3	21.6	33.9	39.7	45.4	51.7
G	Modified—sand cast	T. S.	26,500	23,850	19,050	14,250	10,900	7,850	5050	3100
		Y. P.	10,500	10,000	9,000	7,250	5,000	3,500	2500	1500
		Elong.	7.75	10.5	12.8	13.0	14.8	15.0	21.5	31.0
		Red.	8.39	10.7	14.6	15.4	15.4	17.5	23.8	31.2
C	Sand cast	T. S.	21,750	21,100	19,750	17,500	16,250	11,000	5650	3500
		Y. P.	12,000	11,750	11,000	10,750	10,750	7,250	3750	2250
		Elong.	1.00	1.00	2.00	1.00	1.00	2.50	11.8	17.5
		Red.	0.00	0.00	2.24	0.00	0.00	1.94	18.3	23.3
A	Sand cast—heat treated	T. S.	31,000	29,500	30,500	33,200	18,600	9,450	4000	2650
		Y. P.	13,500	11,500	12,250	14,250	12,250	7,000	2750	1500
		Elong.	7.17	9.00	4.50	1.67	5.38	16.0	46.0	71.0
		Red.	6.30	8.88	6.90	0.00	6.20	26.7	52.3	65.0
E	Permanent mold cast	T. S.	36,000	35,000	33,500	30,050	25,500	13,500	5750	4000
		Y. P.	23,500	21,500	19,500	17,500	15,000	8,000	4500	2450
		Elong.	1.00	1.50	2.00	2.50	3.00	6.50	14.0	23.0
		Red.	0.00	0.00	0.00	0.00	0.00	10.0	23.5	41.5
Y	Sand cast—heat treated	T. S.	37,150	35,750	34,500	33,000	26,100	16,250	8250	3200
		Y. P.	29,000	28,500	27,500	25,000	19,000	7,000	3000	1500
		Elong.	1.00	1.00	1.00	1.00	1.00	1.00	12.5	44.0
		Red.	0.00	0.00	0.00	0.00	0.00	0.00	13.3	39.2

[1] Tensile strength in pounds per square inch.
[2] Yield point in pounds per square inch.
[3] Elongation, percent in two inches.
[4] Reduction of area in percent.

silicate or dichromate. Aluminum is attacked vigorously in the cold by hydrofluoric and hydrochloric acids and less rapidly by sulphuric acid. Pure nitric acid has little effect on aluminum but aluminum is attacked by mixtures of nitric and sulphuric acids, slowly in the cold and much more rapidly when heated. Aluminum and its alloys are quite resistant to many materials encountered in the chemical and food industries and this resistance is responsible for an extensive use.

Several other properties such as light reflectivity, surface behavior in electrolytic and electrostatic condensers, cold forming characteristics, bearing qualities, weldability, ability to radiate or reflect heat, arcing characteristics, etc., may require consideration by the engineer for special applications of aluminum alloys.

Applications of Aluminum Alloys

These are too numerous to attempt to detail. Aluminum alloys are used in every major industry and for a wide variety of functions. The aircraft industry is perhaps most dependent on aluminum alloys for its magnitude and growth, and the transportation industry in general provides the largest outlet.

General and Historical

The development between 1885 and 1890 of a method for producing aluminum economically by Hall in America and Heroult in France provided the foundation for the developments of the aluminum alloy industry. Until about 1910 only the effects of the alloying ingredients in the as cast or in the worked condition were utilized. About this time the heat-treated wrought alloys were introduced in Germany by Alfred Wilm. About 1912 the permanent mold casting industry was started by Cothias in France and in 1914 Doehler, in America, began making pressure die castings of aluminum alloys. Both of these processes contributed to the castings art with respect to physical properties, thinness of sections obtainable and in dimensional control.

The alloys used in the castings industry were usually either aluminum-copper or aluminum-zinc with a small amount of copper, the former being adopted largely in America and the latter in Europe. In 1920, Pacz introduced his modified aluminum-silicon alloy castings commercially in America. Improvement in physical properties was obtained by adding sodium fluoride to a molten alloy containing about 13 percent silicon. The Aluminum Company of America later produced the same result by adding metallic sodium instead of sodium fluoride. The Aluminum Company of America and the Acme Die Casting Corporation introduced the chill-modified aluminum-silicon alloy die castings in America in 1920 and the former company in cooperation with General Electric Company introduced the unmodified or normal aluminum-silicon alloy sand castings a little later. Ternary and more complex alloys in which silicon was used as a definite and important alloying element rapidly became part of the art. In 1921, the Aluminum Company of America introduced in America heat-treated aluminum alloy castings which may be regarded as the last major contribution to the aluminum castings art. Although the heat-treated wrought alloy industry began about eleven years before the heat-treated castings industry, it is estimated that more than 25,000,000 pounds of heat-treated aluminum alloy castings were produced in the United States alone in 1928, an amount considerably in excess of the world's production of heat treated wrought aluminum alloys.

The principal unheat-treated wrought alloy in the aluminum industry is the 1.25 percent manganese alloy. This was introduced in America in 1906 by the Pittsburgh Reduction Company, now the Aluminum Company of America. In the heat-treated wrought alloy field, duralumin was introduced in Germany about 1910, Aludur in Switzerland and Germany apparently about 1921, although much secrecy was attached to the composition and heat treatment at the time. In 1922 the Aluminum Company of America introduced in America 258 alloy which must be given both a solution and precipitation heat treatment to develop maximum strength and hardness. These three types are referred to as the wrought strong alloy group. So great has been the progress in the fabrication of these materials that one company is now making structural shapes about ten inches in the largest cross sectional dimension and 90 feet long.

In the development of the metallurgy of aluminum alloys, many have played an important part. In England, Carpenter, Rosenhain, Gwyer, Edwards, Hansen, Archbutt, Bingham, Seligman, Aitchison, Lea, Bengough, Elam, Gayler, Hudson, Lantsberry and Pannell have contributed much. The National Physical Laboratory has published the results of a large amount of research on the constitution of aluminum alloy systems and on the properties of aluminum alloys. In Germany the names of Wöhler, Heyn, Wilm, Guertler, Meissner, Welter, Glaser, Fraenkel, Schirmeister, Czochralski and others are connected with important contributions on aluminum alloys. In France, DeVille, who with Wöhler may be regarded as the father of aluminum alloys, made important contributions as early as 1858. Later, Minet, Suhr, Guillet, de Fleury and Grard among others have been associated with the advancement of metallurgical knowledge of aluminum alloys. In Japan, Honda and his associates have contributed results of several researches during recent years. In America, Hall, Hunt, Richards, Hoopes, Blough, Gillett, Norton, Merica, Waltenberg, Scott, Freeman, Rawdon, Frary, Edwards, Archer, Dix, Daniels, Stay, Gibson, Pacz, Anderson, Corson, Kempf, Knerr, Richardson, Fink, Keith, Keller, Flick, Hybinette, Lyon, Johnson and Johnston have been important contributors. The development of a satisfactory explanation of the heat treatment of duralumin by Merica, Waltenberg and Scott, then of the United States Bureau of Standards, stimulated alloy development and metal science not only in the aluminum, but in other fields. Also, the production of aluminum of 99.98 percent purity by Hoopes and Frary has made it possible to determine the true effects of each alloying element, and as a result metallographic knowledge of aluminum alloys has been enriched.

Annual production of cast aluminum alloys greatly exceeds that of the wrought alloys. In the castings field, the largest tonnage is in sand castings, second in permanent mold, and least in pressure die castings. Copper may still be regarded as the principal alloying element in the sand and permanent mold casting fields with silicon becoming more of a factor each year. Zinc is an important alloying element in sand castings. Silicon is now the most important alloying element in aluminum die castings.

Magnesium Alloys

Magnesium alloys may be regarded as the newest light weight materials to receive definite and substantial commercial recognition. It is estimated that in 1928 approximately 5,000,000 pounds of magnesium alloy were produced in the world, mostly made and used in Germany, with the United States not a very close second. In Germany and in certain other European countries, these alloys are known as Elektron. "Dow Metal" is a name which has been applied to certain magnesium alloys in America. The principal use is in the form of sand castings, but pressure die castings and wrought products are also in commercial production. Table VIII gives the compositions of magnesium alloys now in commercial production, and some of the physical properties are given in Table IX.

Magnesium, with a specific gravity of 1.74, is approximately one-third lighter than aluminum. It will be noted from Table IX that the alloys combine lightness and strength to a degree which makes them very attractive for engineering purposes. Such information as is available indicates that the endurance properties are good. Young's Modulus of Elasticity (E) is about 6,250,000 for the commercial alloys.

TABLE VIII—APPROXIMATE CHEMICAL COMPOSITION OF MAGNESIUM BASE ALLOYS

Arbitrary Designation	Commercial Designation	Approximate Chemical Composition in Percent (not Including Magnesium or Impurities) Al	Cd	Cu	Mn	Zn	Si	Usual Commercial Form
A	AM-4.4, Dow Metal	4.0			0.4			Rod, sheet, forgings, castings
B	AM-7.4	7.0			0.4			Castings
C	Dow Metal D	8.5	1.0	2.0	0.15	0.5		Castings
D	Dow Metal E	6.0			0.25			Castings or forgings
E	Dow Metal T	2.0	2.0	4.0	0.15			Pistons
F	Electron V1	10.0			0.2–0.5			Die castings and wrought forms
G	Electron AZF	4.0			0.2–0.5	3.0		Castings
H	Electron AZG	6.0			0.2–0.5	3.0		Castings
I	Electron AZM	6–6.5			0.2–0.5	1.0		Rod, forgings
J	Electron SZ					1.7		Extruded products
K	Electron AZ31	3.0			0.2–0.5	1.0	1.4	Rod, forgings
L	Electron Z1b					4.5		Used in dyeing industry
M	Electron AM503	0.2–0.5			0.5–1.0	0.1–0.3		Extruded shapes
N	Electron AZD	5.0	3.0		0.2–0.5	3.0		Extruded shapes
O	Electron Z3					3.0		Extruded shapes
P	Electron V1	10.0			0.2–0.5		2–3.0	Pistons

TABLE IX—TENSILE PROPERTIES AND HARDNESS OF MAGNESIUM BASE ALLOYS

Alloy: Designation from Table VIII	Alloy: Condition	Tensile Properties: Tensile Strength in Pounds per Square Inch	Tensile Properties: Elongation Percent in 2 Inches	Tensile Properties: Brinell Hardness Number
A	Sand cast	23,000	8.0	48
A	Chill cast	30,000	10.0	50
A	Wrought	42,000	18.0	54
B	Sand cast	24,000	5.0	51
B	Sand cast and heat treated	32,000	8.0	51
B	Wrought	44,000	13.0	56
B	Wrought and heat treated	43,000	13.0	50
C	Sand cast	22,000	2.0	58
D	Sand cast	26,000	7.0	52
D	Wrought	42,000	11.0	58
E	Sand cast	21,000	3.0	45
F	Die cast	21,000	3.0	70
F	Wrought	50,000	8.0	70
F	Wrought and heat treated (SP)	57,000	4.0	87
G	Sand cast	26,000	5.0	45
G	Chill cast	30,000	8.0	52
H	Sand cast	26,000	4.0	52
I	Wrought—soft	43,000	14.0	55
I	Wrought—hard	53,000	1.0	65
J	Wrought	33,000	12.0	44
K	Wrought	37,000	15.0	49
L	Wrought	37,000	16.0	45
M	Wrought—soft	33,000	16.0	40
M	Wrought—hard	43,000	2.0	55
N	Wrought—soft	45,000	11.0	60
N	Wrought—hard	56,000	1.0	70
O	Wrought—soft	33,000	16.0	42
O	Wrought—hard	43,000	2.0	60

In recent years progress in manufacture and fabrication has been so marked that the ordinary commercial shapes and sizes of both cast and wrought products are available at prices which represent distinct economy over any other material for aircraft construction. Corrosion seems to be the outstanding barrier to more rapid adoption. The alloys, by the use of a small amount of manganese, are comparable in corrosion resistance with pure magnesium, but both are subject to salt water attack. Further improvement in the inherent resistance of the alloy and effective methods of surface protection are much needed in the art.

In Germany, most of the production of Elektron goes into automobiles, busses and trucks, and a small amount into aircraft. In America, the aircraft industry absorbs most of the alloy production. Increased use of magnesium alloys can be confidently predicted for the future.

Vancoram Review, Vol. 1, No. 1

The Vanadium Corporation of America, 120 Broadway, has put out the first issue of the *Vancoram Review*, a quarterly prepared by its research department. It contains technical and scientific data from the work of the research staff, and a résumé of the current scientific, technical and patent literature of vanadium, its alloys and compounds.

It is perfectly good logic that a metal-user faced with the necessity of a choice among competing alloys, should take the one on which he can find cold facts, and pass up the one that is backed up only by salesmen's claims. Published data, offered for the scrutiny of scientists, is psychologically and actually of more value than carbons of unpublished laboratory tests pulled out of a salesman's brief case. It is good business to spread the real facts as to the properties of one's product.

These compilations of data from all sources, prepared from the coldly scientific point of view, rather than that of the advertising man, are valuable and are appreciated by the consumer, even though he does get them for nothing.

Pamphlets of the type of the *Vancoram Review* and of the bulletins put out by the nickel producers appear to us to be likely to create more good-will toward the firm distributimg them than to the jazzy type of "house organs," which one may glance at if they are well illustrated, but which promptly go in the waste basket.

When a metallurgist gets a pamphlet in which he finds good abstracts, even though naturally only in the field bearing on the products for sale by the firm that prepares it, he is likely to keep it, and to refer to it. He is also likely to feel that a firm that supplies that sort of information is not going to make claims that it cannot back up. It is hard to tell whether a publication of this sort is a paying investment for the firm that prepares it, but it certainly makes for good will, and sooner or later, good will is reflected in the balance sheet.

The *Review* is a good job.—H. W. Gillett.

The New Westinghouse Weldomatic

The Westinghouse Electric and Manufacturing Company announces the development of the "Weldomatic," a new and greatly improved automatic welding outfit. The Weldomatic equipment is complete with electrode feeding device, control cabinet and operator's panel. It is designed to operate with equal satisfaction from either Westinghouse variable voltage or constant voltage welding motor generator sets.

The growth and economy of automatic arc welding in the metal working industries has brought about a demand for an automatic welder of very compact dimensions to facilitate mounting on the welding tools, and furthermore, a welding device that is equal in reliability of the usual shop tool.

The Weldomatic has been developed by the Westinghouse Electric and Manufacturing Company to meet these conditions. It automatically strikes and holds an arc between an electrode and the work to be welded without the aid of an operator other than to press the starting button. The feeding device is a most compact design which permits its ready application to work handling tools. The drive motor is mounted in a cylindrical frame which supports the nozzle assembly. The nozzle has adjustments for being moved in two planes, and the nozzle assembly can be reversed very easily to be either a right-hand or a left-hand assembly.

Heat Resisting Castings

At the recent National Metal Exposition at Cleveland the Ohio Steel Foundry Company of Springfield, Ohio, one of the leading manufacturers of Heat Resisting Castings, featured a display of centrifugally cast Fahrite tubes, this being the first time that centrifugal castings of nickel-chromium alloy had been shown in this country. Other features of their exhibit were samples of castings made from Fahrite N-1 and Fahrite C. S., and also a display of their Heat-Saver valves for open hearth furnaces, etc. Those who had no opportunity of visiting the show in Cleveland can obtain literature descriptive of these products from the Ohio Steel Foundry Company, Springfield, Ohio.

Nickel and Chromium Extend the Field of Application of Iron Castings

By F. B. Coyle*

On many occasions during the past few years prominent executives in the grey iron industry have expressed the view that the industry was not maintaining the same forward progress as other casting industries. Two factors have contributed largely in the development of this situation. The first is technical. Adequate information regarding the properties and application of cast iron has not been submitted in a form concise enough to be readily available to those most interested. Standard engineering handbooks usually describe only the poorest grades of cast iron. Research and progress have been described in transactions of highly scientific organizations and trade publications not readily accessible to engineers and designers. This fact has been recognized recently and committees of the American Society for Testing Materials and the American Foundrymen's Association are preparing a necessary and concise digest of the properties and applicability of iron castings in usable form. The second reason is economic and naturally arises from the first. Castings have been purchased primarily on a basis of lowest cost, the question of quality being disregarded.

It has been recognized that the field of utility of grey iron castings was restrained due to the limitations of the material itself. However, investigation during the past few years has demonstrated that the addition of alloying elements extends the applicability of cast iron considerably.

The value of alloying elements in this field may be considered in two distinct aspects.

1. The effect of relatively small additions in grey iron for general applications.

2. The effect of large amounts for applications of a special nature.

General Grey Iron Applications:

The following characteristics, most of which are of a practical nature, are beneficially modified by small additions of nickel and chromium—

1. Grain refinement.
2. Reduction of chill.
3. Machinability.
4. Density.
5. Resistance to wear.
6. Strength.

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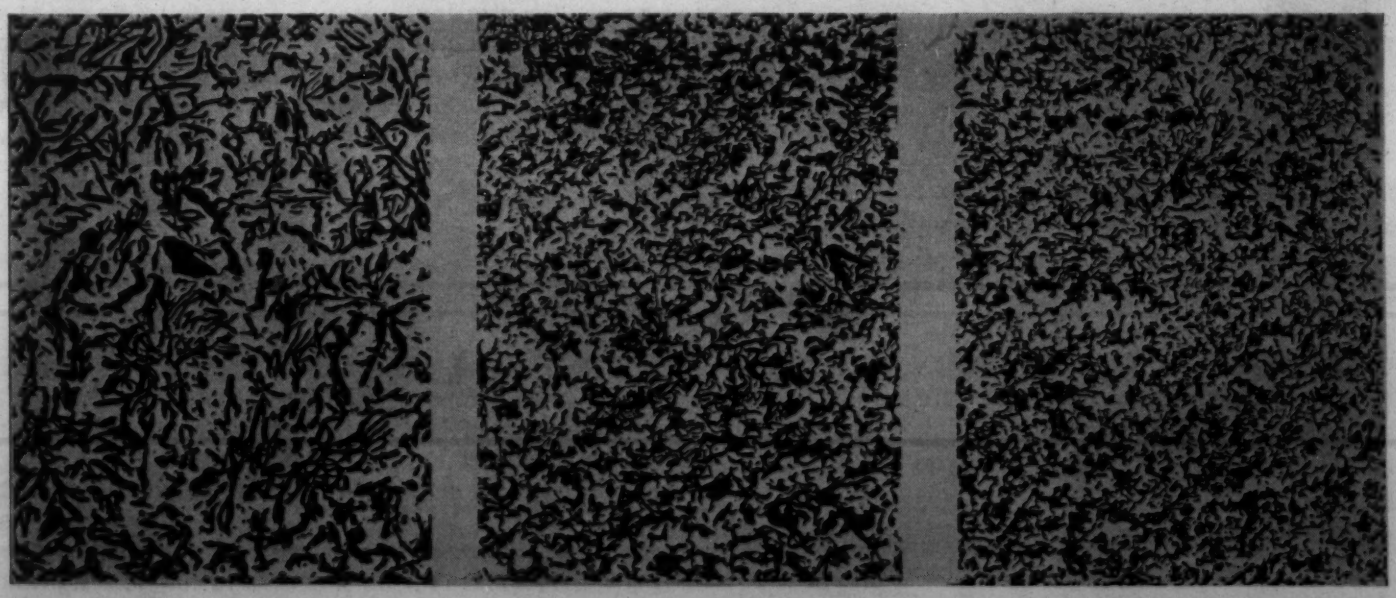
Grain Refinement:

The texture of a broken surface of cast iron is commonly denoted "the grain." The appearance of such a fracture may be relatively fine or coarse. Grain is the yard stick by which most practical foundrymen measure the quality of a casting. For this reason, it must be considered important. The finer the grain the greater is the indicated strength and quality of a casting. Grain is really a rough measure of the size of graphite flakes in a given casting. The photomicrographs in Fig. 1 show the decrease in graphite size accompanying the addition of nickel in grey iron. The mechanism of this action is twofold. In steel, the addition of alloying elements is usually accompanied by an increased number of crystallization nuclei during solidification. This is also true of cast iron. At elevated temperatures after solidification nickel inhibits mobility of graphite and prevents coalescence or growth of existing flakes. Thus the inhibiting power of nickel in conjunction with the baffling effect of a greater number of crystalline grains prevents substantial growth of graphite flakes and produces finer grain.

Reduction of Chill:

Oftentimes the foundryman is troubled by the occurrence of chill, that is, thin sections may contain zones of hard white iron. At other times it may be necessary to reduce silicon so low in order to obtain strength and density that corners and edges chill white. In such cases nickel or nickel and chromium in balanced proportions is of distinct advantage. Nickel acts as a graphitizer in a manner similar to silicon but with only half the intensity. In its action as a graphitizer nickel causes cementite in iron to break down into pearlite and graphite. This is clearly shown in Fig. 2. Diagrammatic sections of step bars of various compositions are shown. Step bar castings are $2^1/_2$ inches wide and have a section $^1/_8$ inch thick and 6 inches long, as well as sections $^1/_4$, $^1/_2$ and 1 inch thick, each 3 inches long. Their purpose is to demonstrate the variation of hardness and fracture in different sections and of variations in composition on these properties. The casting containing 1.13 percent silicon was white throughout the $^1/_8$ inch section and most of the $^1/_4$ inch section as shown by the black filling. The remainder of the $^1/_4$ inch and most of the $^1/_2$ inch sections were mottled as shown by the grey filling. About one-third of the $^1/_2$ inch and all of the 1 inch sections were grey. The Brinell hardness varied from 207 to 364 as shown. The transverse breaking load and tensile

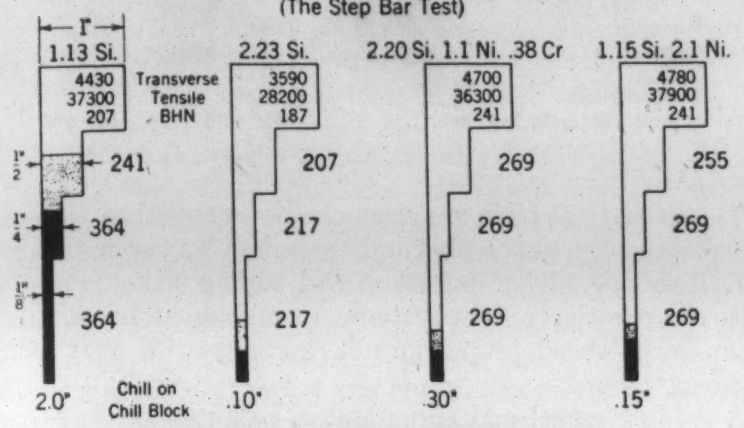


No Nickel 0.73% Nickel 2.12% Nickel

Effect of Nickel in Refining Grain of Grey Iron Arbitration Bars of Cupola Iron (3.45% Carbon, 1.0% Silicon) (Magnification . . . 30)

strength given were obtained from arbitration bars. Reduction of chill can be obtained as shown by either raising silicon or adding nickel to the low silicon iron. However, adding silicon reduces strength as well as hardness. Since nickel has half the greying intensity of silicon, the addition of 2.1 percent nickel produces in a casting containing 1.15 percent silicon the same grey characteristics as if silicon had been increased to 2.20 percent. Nevertheless, it will be observed that the strength is the same as for low silicon iron.

Hardening Cast Iron by Nickel plus Chromium
(The Step Bar Test)



Base composition 3.15 C., .40 Mn., .30 P., .05 S.
All heats crucible melted, green sand cast
Step bar 15"x 2 1/4"; steps 3" and 6"; chill bar 1"x 2"x 4"
Transverse tests on arbitration bars

A striking example of this principle is shown in the case of a manufacturer of automobile cylinder blocks having a bore $3^1/_8$ inches in diameter. When made in plain iron the Brinell hardness was 150 to 160. The structure was partly ferritic. By adding 1.5 percent nickel and lowering silicon to 1.8 or 2.0 percent, as shown in Table 1, the Brinell hardness was increased to 180 to 190 and the structure changed to practically complete pearlite. Consequently, due to the improved structure and greater hardness the resistance to wear was practically doubled. No difference was noticed in machinability.

Table 1—Composition of Cylinder Blocks

	Alloy Iron, Percent	Plain Iron, Percent
Nickel	1.25–1.50	None
Silicon	1.80–2.00	2.20–2.40
Total carbon	3.20–3.40	3.20–3.40
Manganese	0.40–0.50	0.40–0.50
Sulphur	Under 0.10	Under 0.10
Phosphorus	Under 0.20	Under 0.20

A production problem which often presents itself to the foundryman is the need to make a small quantity of strong castings while his foundry is standardized on producing high silicon iron. This is particularly true when the quantity of castings desired is too small to warrant running a special mixture. This can be accomplished as shown in Fig. 2. The addition of nickel and chromium in balanced proportion will produce in a high silicon iron the same strength as a low silicon iron but with the added advantage of the same grey characteristics as the high silicon iron.

By "balanced proportion" is meant that nickel must amount to approximately three times the chromium contained. This is clearly shown by Piwowarsky's results given in Table 2.

Table 2—Effect of Varying Nickel to Chromium Ratio on Combined Carbon of Grey Iron (Piwowarsky)

	1	2	3	4	5
Total carbon	3.70	3.68	3.85	3.77	3.72
Silicon	1.82	1.75	1.69	1.75	1.81
Nickel	0.00	0.39	0.41	0.39	0.72
Chromium	0.00	0.49	0.29	0.14	0.15
Ratio Ni to Cr	0.00	0.80	1.40	2.70	4.80
Combined carbon	0.44	0.72	0.58	0.48	0.38

Carbon and silicon are practically constant throughout this table. Nickel is practically constant in 2, 3 and 4 but higher in the last. These compositions are very high in carbon as well as silicon. As silicon and carbon are reduced, the effect is greatly accentuated. A practical example of the application of nickel and chromium is shown in the following case of cams used on a special production machine. It was necessary that the surface be hard to resist wear but soft enough to be machined. When made in plain iron the Brinell hardness was 170. If silicon were lowered trouble would have been encountered in machining, due to chilled edges. By adding nickel and chromium in balanced proportion, as shown below in Table 3, the Brinell hardness was increased to 240, the cams were machinable, and chill was totally absent. At the same time the service life was increased from four months for the plain iron cams to more than two years for the alloy iron cams.

Table 3—Composition of Grey Iron Cams

	Alloy Iron, Percent	Plain Iron, Percent
Nickel	3.00	None
Chromium	0.90	None
Silicon	1.40	1.50
Carbon	3.30	3.30

Machinability:

Not only from a practical point of view, but an economical one, machinability is a vital requisite in the production of castings. In some fields high-speed machining is desirable. However, it must be borne in mind that maximum ease of machining does not always go hand in hand with high quality or maximum service. Two instances of machinable castings have already been referred to. The detrimental effect of chill has been referred to also. White or chilled iron rapidly wears out tools and entails great cost in tool material, tool grinding and lost time in tool replacement. This is evident from the experience of many manufacturers of automobile pistons. If silicon were reduced sufficiently to eliminate internal shrinkage in piston pin bosses, the thin or skirt end would be chilled. In such cases it would be necessary to anneal the pistons at 1450° F. or higher. This treatment, while increasing machinability, softened the pistons too much and destroyed strength and resistance to wear. By lowering silicon slightly and adding 0.90 percent nickel, as shown in Table 4, the piston castings were rendered entirely grey and machinable. The annealing range was dropped to 900 to 1000° F. to eliminate casting stresses only. This treatment does not affect either hardness, strength or structure.

Table 4—Composition of Pistons

	Alloy Iron, Percent	Plain Iron, Percent
Nickel	0.80–1.00	None
Silicon	2.40–2.55	2.60–2.75
Total carbon	3.40	3.40

The addition of nickel, or nickel and chromium in balanced proportion, in sufficient quantities progressively changes the structure of pearlite to sorbite. In this manner t iis possible to increase Brinell hardness considerably above that of plain iron without causing chill or free carbide in excess of the normal pearlitic proportion. Brinell hardness of 220 can be considered the maximum limit at which plain iron can be machined. Nickel-bearing iron with Brinell hardness as high as 290 has been successfully machined.

Density:

It is necessary at times to construct castings with widely varying sections. A thin section cools at a much faster rate than a heavy one. Hence, a thin section will be finer grained, stronger, harder and denser than a heavy one. If silicon were reduced so that a dense, strong metal were obtained in a heavy section, light sections would be difficult or impossible to machine. Additions of nickel in such a case will make it possible to obtain a sound, dense structure in the heavy section and will render the light sections machinable. This is shown in the example of a pressing machine steam chest casting. The sections in this casting varied from $^1/_4$ inch on the edge to $1^1/_2$ inch at the bosses. When made of iron containing 2.25 percent silicon the edges were machinable but the bosses open and porous. When silicon was reduced to 1.50 percent, the bosses were sound and dense but the edges unmachinable. The ad-

dition of 1.0 percent of nickel, as shown in Table 5, to the lower silicon iron produced a casting which was satisfactory in both respects.

Table 5—Composition of Pressing Machine Steam Chest

	Alloy Iron, Percent	Plain Iron, Percent
Nickel	1.00	None
Silicon	1.40	2.25
Total carbon	3.30	3.40
Phosphorus	0.20	0.60
Sulphur	0.10	0.08
Manganese	0.65	0.45

The author published a formula and table of constants in the Annual Report of Committee A-3 of the American Society for Testing Materials in June, 1929, which show how the strength of plain iron decreases with increase in section. The constants are given in Table 6.

The formula stated—

$$\text{Tensile Strength} = \frac{\text{Constant (Table 6)}}{d^{1/2.02}} \quad \ldots\ldots 1$$

where "d" is the diameter of the casting shows that strength diminishes with increase in size. Subsequent investigations enabled the author to construct the following table of constants for iron containing 1.0 to 2.0 percent of nickel (Table 7).

The formula derived is as follows:

$$\text{Tensile Strength} = \frac{\text{Constant (Table 7)}}{d^{1/3}} \quad \ldots\ldots 2$$

Table 7 shows uniformly higher constants than Table 6 and formula 2 shows a lesser slope than formula 1. Consequently, it is shown that increased density in heavy sections of nickel iron produces greater strength than in plain iron.

Resistance to Wear:

Ferritic irons are very soft and wear very rapidly. This was demonstrated clearly in tests for the Navy Department.[1] As hardness increases pearlitic structure and resistance to wear increases. Increase of hardness beyond this point is accompanied in plain iron by increase of free cementite. With this condition resistance to wear is decreased. However, if it is possible to increase hardness without producing free carbide resistance to wear will be increased. This can be accomplished by using nickel or nickel and chromium. Two examples have already been mentioned. The same principle is in use in forming dies for forming automobile bodies and fenders and boiler plate. Such alloy iron dies wear $4^1/_2$ times longer than plain iron dies. In one service test alloy iron die blocks made of the composition shown in Table 8 with a section $7^1/_2$ inches thick used in forming sheet steel gave 140,000 impressions as compared with 12,000 impressions for plain iron.

[1] "Properties and Heat Treatment of Cast Iron for Diesel Engines," F. B. Coyle, *Trans. A. S. S. T.*, September, 1927.

Table 8—Composition of Die Blocks

	Alloy Iron, Percent	Plain Iron, Percent
Nickel	2.50–3.00	None
Chromium	0.60–0.80	None
Silicon	1.25	1.00
Total carbon	3.00	3.00
Brinell hardness, 1–2″ sec.	240–260	180–200

Strength:

The strength of plain grey iron can be increased by the aid of the alloying elements nickel and chromium by two methods:

1. Reducing silicon or carbon and adding nickel in castings with comparatively light sections, or adding nickel and chromium in balanced proportions in castings with very heavy sections.

2. Adding nickel and chromium in balanced proportions to high silicon iron castings.

A leading manufacturer of automobiles encountered difficulty due to cast iron fender forming dies breaking. Silicon was reduced from 1.25 to 0.90% and 1.60% nickel added as shown in Table 9. The dies were $1^1/_2$ to 2″ thick.

Table 9—Composition of Fender Forming Dies

	Alloy Iron, Percent	Plain Iron, Percent
Silicon	0.90	1.25
Nickel	1.60	None
Sulphur	0.120	0.095
Phosphorus	0.18	0.20
Manganese	0.70	0.65

The plain iron dies would break apart after drawing 3000 fenders. The adjustments shown increased the strength to such an extent that none of the dies were broken after drawing 16,000 fenders. Reduction in carbon has the same effect as a reduction in silicon and can be effected by using large percentages of steel in the cupola charge. This is shown in the case of hydraulic ram plungers. These castings were 4 to 8″ thick

Table 6—Table of Constants to be Used in Formula 1 for Relation of Strength to Section of Plain Cast Iron Round Bars

	Total Carbon												
Silicon	2.50	2.60	2.70	2.80	2.90	3.00	3.10	3.20	3.30	3.40	3.50	3.60	3.70
1.00	...	...	...	...	...	42,300	41,000	39,400	37,800	36,500	35,200	33,850	32,500
1.10	...	...	...	...	...	44,400	42,800	41,250	39,400	37,300	35,550	33,300	30,950
1.20	...	...	...	...	...	45,000	43,400	41,800	39,700	37,550	35,550	33,300	30,700
1.30	...	...	...	45,500	45,000	44,200	42,800	40,700	38,600	35,700	33,050	30,150	27,500
1.40	...	...	...	45,000	42,300	42,800	41,250	38,900	36,000	33,050	30,400	26,500	25,900
1.50	42,300	44,400	45,000	44,400	43,100	41,250	39,400	37,000	34,400	31,750	29,350	27,000	24,850
1.60	41,500	43,600	44,200	43,400	41,800	39,950	37,800	36,500	31,250	30,400	28,300	25,900	23,800
1.70	40,700	42,300	42,800	41,800	40,200	38,100	36,000	33,050	31,150	29,100	27,000	23,750	23,300
1.80	39,700	40,700	41,000	40,200	38,350	36,500	34,400	32,500	30,150	28,000	25,900	24,050	22,200
1.90	39,400	39,700	39,700	38,600	37,000	35,200	33,300	31,150	29,100	27,250	23,750	23,300	21,700
2.00	38,900	38,600	37,800	36,500	35,200	33,600	31,750	30,150	28,000	26,200	24,350	22,500	20,900
2.10	38,350	37,550	36,750	35,550	33,850	32,500	30,950	29,100	27,250	25,400	23,800	21,950	20,350
2.20	37,550	36,750	35,700	34,400	33,050	31,750	30,150	28,300	26,450	24,850	23,300	21,400	19,850
2.30	37,300	36,300	34,900	33,600	32,300	30,700	29,100	27,500	25,900	24,050	22,750	20,900	19,300
2.40	36,750	35,550	34,400	32,800	31,450	29,900	28,300	26,700	25,050	23,550	22,200	20,350	18,800
2.50	36,500	34,900	33,300	32,000	30,400	29,100	27,500	25,900	24,350	23,000	21,700	20,100	18,500

Table 7—Table of Constants to be Used in Formula 2 for Relation of Strength to Section of Nickel Cast Iron Round Bars

	Silicon																	
T. C.	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90	2.00	2.10	2.20	2.30	2.40	2.50
2.50	...	...	38,000	40,000	42,000	44,750	45,250	46,250	46,750	47,000	47,000	46,750	46,500	46,250	45,750	45,000	44,150	43,500
2.60	...	...	40,250	42,250	43,500	45,000	46,000	47,000	47,250	47,500	47,100	46,650	46,250	46,000	45,150	44,250	43,500	42,850
2.70	36,750	39,250	41,750	43,750	44,750	45,750	46,500	47,500	47,650	47,500	47,000	46,500	46,000	45,250	44,500	43,500	42,500	41,750
2.80	39,250	41,250	43,000	44,500	45,500	46,250	47,000	47,750	47,750	47,400	46,750	46,000	45,500	44,500	43,500	42,500	41,500	40,650
2.90	40,750	42,250	44,500	45,000	45,750	46,500	47,100	47,750	47,500	47,000	46,500	45,500	44,500	43,500	42,500	41,250	40,250	39,000
3.00	40,750	42,250	44,500	44,750	45,500	46,500	47,000	47,500	47,000	46,500	46,250	44,750	43,500	42,250	41,250	39,500	38,500	37,250
3.10	39,750	41,000	42,250	43,500	44,500	45,500	46,500	46,500	46,000	45,250	44,250	43,250	41,750	40,500	39,250	37,750	36,500	35,150
3.20	38,500	39,750	40,500	41,750	43,500	44,000	45,250	45,000	44,250	43,350	42,250	41,000	39,500	38,250	37,000	35,500	34,500	32,250
3.30	36,500	37,750	38,500	40,250	41,250	42,250	38,000	42,750	42,000	40,750	39,250	38,000	36,500	35,500	34,250	33,250	32,000	30,650
3.40	34,500	35,750	36,750	38,250	38,750	39,750	40,500	40,000	39,250	38,000	36,750	35,250	34,000	33,000	32,000	30,750	29,750	28,500
3.50	32,500	33,500	35,000	36,500	37,000	37,500	37,500	37,250	36,500	35,350	34,250	33,000	32,000	31,000	30,000	28,750	27,750	26,500

and weighed 5600 lb. each. Carbon was reduced by increasing steel in the charge from 35 to 70%, as shown in Table 10. Nickel was also added.

Table 10—Composition and Charge for Hydraulic Ram Castings

	Alloy Iron, Percent	Plain Iron, Percent
Total carbon	2.98	3.40
Nickel	1.82	None
Silicon	1.03	0.92
Sulphur	0.153	0.098
Phosphorous	0.104	0.43
Manganese	0.62	0.87
Steel scrap	70.0	35.0
Foundry scrap	28.0	45.0
No. 3 pig	None	20.0
Ferro-silicon (50%)	2.0	None

These changes increased the transverse strength from 4400 lb. for plain iron to 5600 lb. for the alloy iron.

The principle of strengthening high silicon iron has already been described under the heading "Reduction in Chill." It is well illustrated in the case of hydraulic jack castings. These castings were $^3/_8$ to $^7/_8$" thick and were required to withstand 10,000-lb. hydrostatic pressure. When made of low alloy composition all castings either leaked or cracked. Silicon was reduced slightly and nickel and chromium added, as shown in Table 11.

Table 11—Composition of Hydraulic Jack Castings

	Satisfactory Alloy Iron, Percent	Unsatisfactory Alloy Iron, Percent
Nickel	1.50	0.11
Chromium	0.50	0.19
Silicon	1.50	1.75
Sulphur	0.09	0.08
Phosphorous	0.20	0.20
Manganese	0.65	0.65

Three thousand castings were made from the new composition. None cracked and only two of the three thousand castings leaked at 10,000 lb. hydrostatic pressure.

High Strength Cast Iron:

Many engineers have expressed the opinion that if it were possible to obtain a cast iron with strength considerably above that of even the best grades of cast iron or semi-steel formerly obtainable, it could be used extensively where ductility was not essential but where strength and resistance to wear were desirable. Such a material would be cheaper than its competitors, steel and malleable iron, could be more readily cast and would constitute a very useful addition to our present ferrous casting materials. It would be intermediate between ordinary plain iron and steel. Two basic conditions have been found to control the production of high strength cast iron. The first is that carbon should be lower than obtained in cast iron produced by conventional methods; the second is that carbon must be present as a very fine, evenly distributed graphite. The carbon content should be preferably between 2.50 percent and 3.10 percent. This is low but it can be consistently obtained. The silicon can vary between 1.25 percent and 4.00 percent. While high strength can be obtained without the use of alloys, the gain in strength is inconsiderable in comparison with that obtained by the use of nickel or nickel supplemented by other alloys. Nickel can vary between 1.0 percent and 4.5 percent. Other alloys can be used to supplement nickel for special purposes. The particular composition used will depend upon the strength desired and the use to which the castings will be submitted. In order to obtain the desired low carbon it is necessary that the charge consist of at least 75 percent of steel scrap. The balance can be either cast iron scrap or high strength return scrap. It may be necessary to also charge some ferro-manganese and ferro-silicon. The charge should be so adjusted that the silicon of the metal as it leaves the cupola should not be more than 0.75 percent and the manganese between 0.50 and 0.80 percent. This will insure a thoroughly deoxidized and degasified melt. If this melted metal were cast directly the castings would be white. While the molten metal is flowing over the spout into the ladle ferro-silicon or ferro-silicon and nickel are added to cause the iron carbide to decompose and precipitate graphite. Castings made from this metal will be grey and possess the property of exceptionally high strength.

Table 12 summarizes the general properties of nickel-bearing high strength cast iron.

Table 12—Composition and Properties of Nickel-Bearing High Strength Cast Iron

Total carbon	2.50 to 3.10%
Silicon	1.25 to 4.00%
Nickel	1.00 to 4.00%
Transverse breaking load	4500 to 8000 lb.
Deflection	0.110 to 0.250"
Tensile strength	50,000 to 70,000 lb./in.^{2}
Compressive strength	165,000 to 190,000 lb./in.^{2}
Elastic limit tension	10,000 to 12,000 lb./in.^{2}
Elastic limit compression	25,000 to 40,000 lb./in.^{2}
Modulus of elasticity (E) tension	10,000,000 to 17,000,000 lb./in.^{2}
Modulus of elasticity compression	25,000,000 to 30,000,000 lb./in.^{2}
Brinell hardness	220 to 260
Fatigue limit	56% of tensile strength

Although the Brinell hardness is high this iron can be machined as readily as a high grade plain iron with a Brinell hardness of 200. It also has about four times the resistance to impact that plain iron has. It has already been successfully used for:

Cyliners and liners for diesel engines.
Gear casings.
Crusher frames.
Pump and compressor parts.
Piston rings.
Hoist drums.
Gears.
Superheated steam chambers and valves.
Forming dies.
Cams, etc.

The author has attempted in this brief survey to indicate examples of how the alloying elements nickel and chromium can be used not only as foundry tools but to extend the use of common grey iron into special and broader fields. No attempt has been made to describe at present the application of high alloy content irons for special applications. While these irons have already been successfully applied on a broad scale for the following purposes:

1. Heat resistance.
2. Corrosion resistance.
3. Non-magnetic application.
4. Martensitic chilled iron.
5. Strength at elevated temperatures.

Results of research and service tests have not been coordinated sufficiently to warrant publication at this time.

Instruction for Brass Foundrymen

We are informed by Mr. W. F. Graham, of the Ohio Brass Company, Mansfield, Ohio, who is Chairman of the Non-Ferrous Shop Operation Course of the American Foundrymen's Association, that at the next Convention of the Association to be held in Cleveland, May 12 to 16, 1930, there will be given the Non-Ferrous Shop Operation Course for the brass foundrymen along the lines of that given in recent years for the grey iron interests.

The subjects dealt with will include crucible, open fire and electric furnace melting practice. The matter of gating will be discussed as well as the effect of pouring temperatures and pouring practice.

The course will be held at 4:00 p.m. during the days of the meeting and each subject will be in charge of a leader who is an authority on the particular phase of brass foundry practice.

The complete program of this activity has not yet been arranged, but will be announced later in these columns.

A New Potentiometer Pyrometer Recorder

A new Potentiometer Recording Pyrometer developed by Wilson-Maeulen Company, New York, has a temperature record chart 12″ wide, and shows a number of other new features of mechanical and electrical design.

In this potentiometer recorder, when the measured voltage from the thermocouple changes, as a result of temperature change at the thermocouple, the galvanometer pointer deflects in the corresponding direction.

At intervals of 10 seconds a boom descends and grips the pointer firmly while two sensing fingers, moving in a vertical plane, approach the pointer from each side, exploring for the location of the pointer, and if either finger finds the pointer deflected and away from its central or null position, a roller ratchet dog is released by the finger, causing a drum to turn.

By means of a violin string wound around the drum and passing over pulleys at each side of the chart and attached at opposite sides of a carriage, the motion of the drum in either direction is transmitted to the carriage which is adapted to travel back and forth across the whole instrument.

The carriage carries the pen which marks the chart in its travel, and a contact brush that rides on the potentiometer slide wire.

The selective operation of the drum's rotation, both in direction and extent, moves the contact on the slide wire so as to bring the galvanometer back towards its null or undeflected position, and at the same time moves the recording pen to record on the chart the temperature of the thermocouple.

changes are slow and long periods of time are involved, the slow speed condenses the record and makes observation of trends and cycles easier. For rapidly fluctuating temperatures and short cycles of operation, the faster speeds allow more detailed analysis of temperature changes.

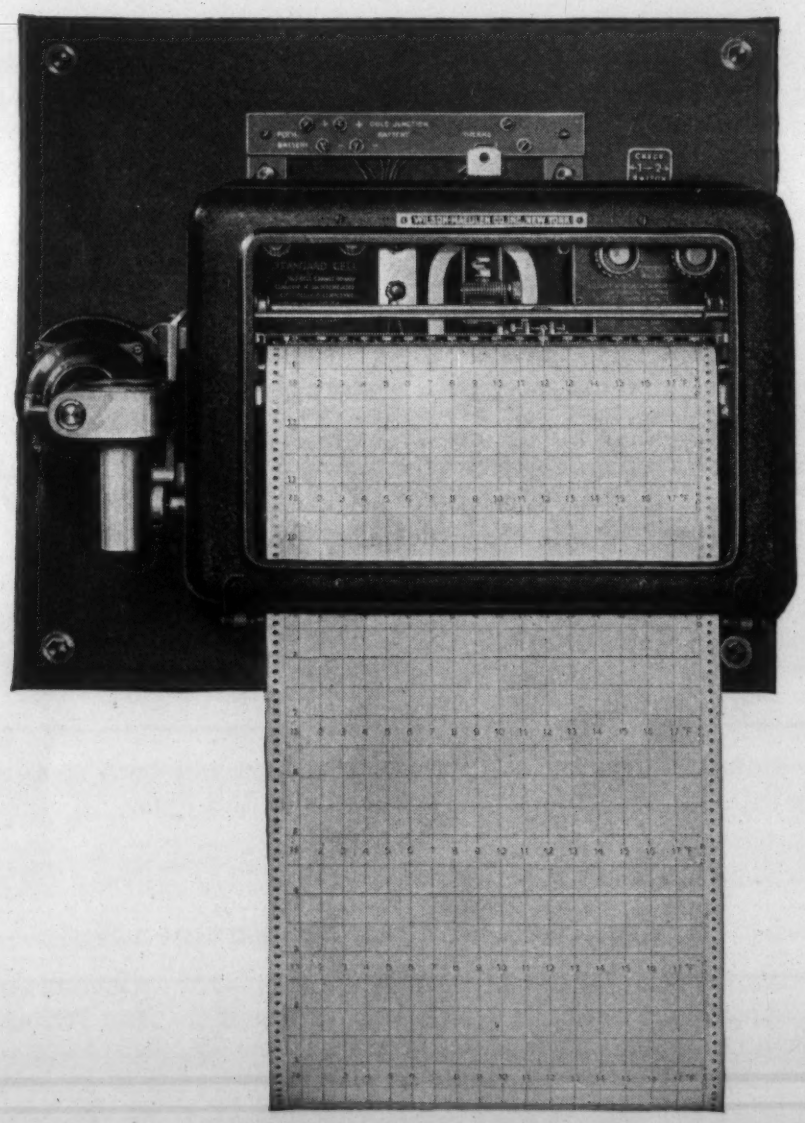
One of the interesting features is the ink developed by Wilson-Maeulen Company for this recorder. The ink has a brilliant red color and dries quickly on the record before the chart emerges from the case, so that the ink does not smear in passing through the paper slot.

Among the new advantages of this recorder is a provision for easily and quickly adjusting the sprocket at one end of the paper roller as to distance from the sprocket at the other end of the roller. This permits adjustment to accommodate for any variation in the width of the chart paper due to atmospheric conditions.

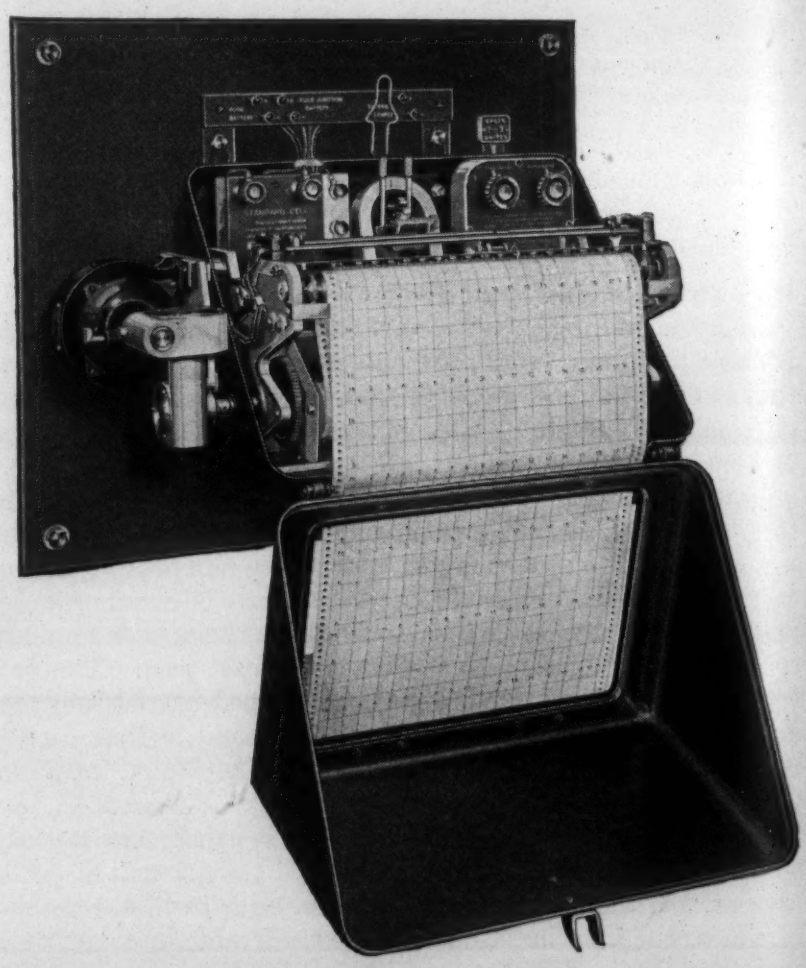
Changes in the temperature of the thermocouple cold junction are automatically compensated for in the instrument by an electric cold junction compensator, similar to the automatic compensators successfully used on all types of Wilson-Maeulen pyrometers for the past several years.

An external drive unit, consisting of an ample sized motor and double worm and gear speed reducing system, located outside the instrument case, furnishes power to the instrument mechanism.

This drive unit is identical with the drive unit satisfactorily employed on Wilson-Maeulen automatic temperature controllers for a number of years, and is supplied with this recorder for either 110 volts or 220 volts alternating current.



Model 8201 Potentiometer Pyrometer



Inside Arrangement of Recorder

Great width of chart, which provides a very open scale, and extremely legible printing of temperature lines and numbers on the chart, together with the bright and contrasting color of the ink used, makes it possible to read the chart at a considerable distance from the instrument.

A choice of three chart speeds, namely $^3/_4$″ per hour, $1^1/_2$″ per hour and 3″ per hour, permits the user to secure the chart speed most suitable for his needs. On operations where temperature

The drive unit provides ample power for operating more than one instrument, and the design is arranged so that a group of recorders, or a group combining this recorder and the Wilson-Maeulen automatic temperature control pyrometer, can be operated by one drive unit.

For low temperature operations, from 600° F. down to 0° F. or lower, this same recorder is supplied to operate as an electric thermometer employing resistance bulbs.

The wide chart of this instrument, its rugged mechanical construction, ample motive power and many other desirable features, make it of particular interest to industrial pyrometer users for all types of service.

Critical Abstracts

Dr. Gillett, the editorial staff and specially selected contributors will prepare abstracts of a critical nature on articles of special importance. The current literature will be covered in the Abstracts of Current Metallurgical Literature.

Oxygen's Role in the Electrolytic Corrosion-Testing of Copper and Nickel in Sodium Chloride Solutions

Just as in any contract, or any marriage, there are two parties to be considered, so in corrosion problems it is necessary to consider not only the metal that is attacked, but the corrodent as well. One would not reasonably expect milk and nitric acid to act alike on a metal, yet it was not so long ago that the advertising staff of a well-known steel company drew just as foolish an analogy in advertising which intimated that tests in hydrochloric acid evaluated the resistance of steel products to atmospheric attack. Fortunately the metallurgical staff appears to have persuaded the publicity man that the advertisement was technically unsound.

But much smaller differences in the nature of the corrodent than those between milk and HNO_3, or HCl and air, may very considerably affect the corrosion process. Some of these differences are still but slightly appreciated by many who make corrosion tests. Any piece of work that tends to show how pitfalls in the methods of corrosion testing may be avoided will therefore be gratefully received.

Similarly, any information that makes it possible to use really accelerated methods of corrosion testing is well worthwhile. Since nearly everyone agrees that many types of corrosion are electrolytic in their nature, it is logical to look toward electrolytic methods of testing.

As a part of an extended program of study of the way conditions of the tests themselves affect the results of accelerated corrosion tests, Rawdon and Tucker, of the Bureau of Standards, have just reported[1] on a study of electrolytic corrosion testing as affected by oxygen taken up by the solution from the atmosphere above it.

The metals used were copper and nickel, each by itself, and the solution was the same throughout all the tests, normal sodium chloride being used.

Since the information given by the electrolytic method is generally obscured at high current densities, the significant part of the curves shown by Rawdon and Tucker is at the lower current densities. The specimens of sheet metal were held in a Haring cell, Fig. 1, or in a similar one with glass ends when totally submerged specimens were tested, so that the current density would be uniform over the sheet. The middle electrode is the anode, both sides being corroded.

By putting the cell under a bell jar the atmosphere could be air, oxygen or nitrogen, as desired.

If nothing in the specimen or solution alters the situation, a given current density will produce a definite amount of anode attack, i. e., loss of weight, according to Faraday's law. So the applied voltage necessary to produce that current density is a measure of the reluctance of the metal to dissolve anodically; the higher the voltage needed, the more resistant is the metal to anodic attack. If the anode attack is just what is calculated from Faraday's law, then the test tells little. If the "anode efficiency" is less than 100% it means that the specimen tends to become passive, i. e., more noble and less readily attacked. If it is greater than 100%, it means that some other source of current beside the externally applied voltage is present, and increases the corrosion. Such a parasitic current may arise from inhomogeneity of the metal specimen itself, or from inhomogeneity of the solution, some sort of a concentration cell being set up.

Since the condition of the solution varies with the amount of corrosion product that has been formed, one has to calculate the theoretical anode loss from the actual current density produced by the applied voltage, so Faraday loss (100% anode efficiency) curves have to be plotted to correspond to each set of data. By comparing the computed and the actual losses of weight and plotting them against applied voltage the resulting curves give a picture of the deviation from the theoretical attack.

Such curves are shown in Fig. 2 for totally submerged copper specimens. The metal behaves as a much more noble metal when all oxygen is excluded by nitrogen, than when oxygen is present over the solution, as long as the applied voltage, for the conditions of test, is below one volt. Above that the curves fall near each other and no clear conclusions could be drawn from a test at high voltage and current density. At low current

[1] H. S. Rawdon, and W. A. Tucker; "The Effect of Oxidizing Conditions on Accelerated Electrolytic Corrosion Tests," *Bureau of Standards Journal of Research*, **3**, 375 (1929).

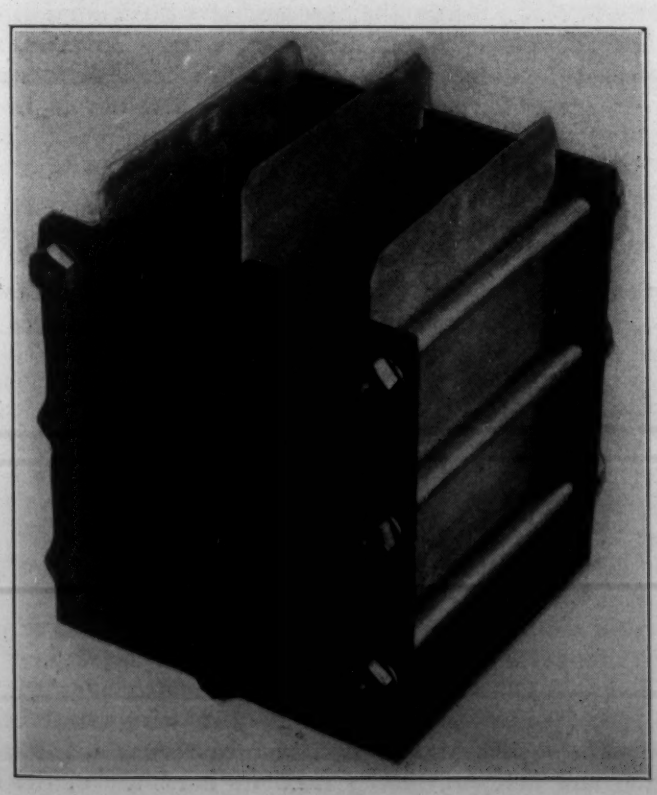


Fig. 1

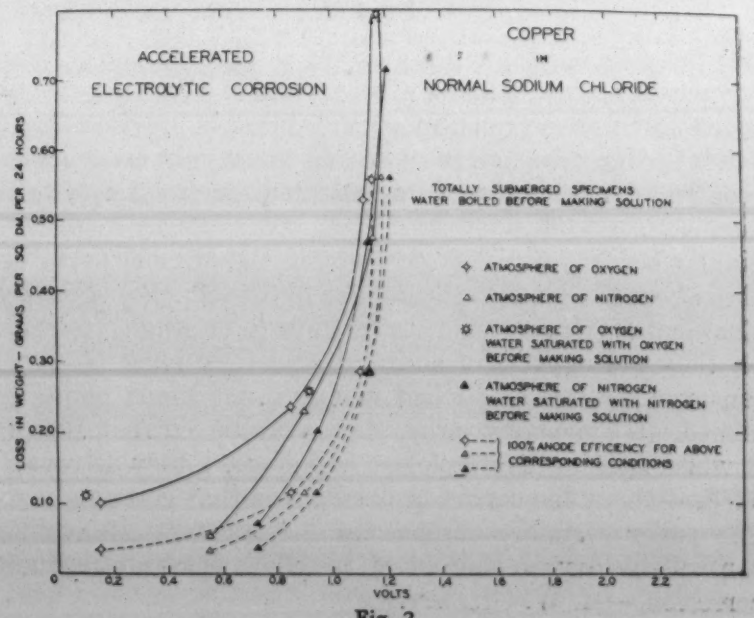


Fig. 2

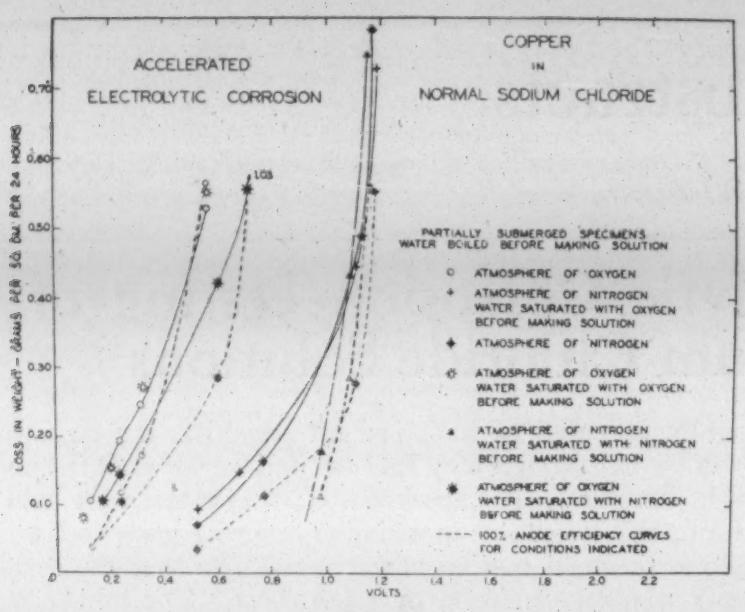


Fig. 3

densities, however, the difference is very striking. In the oxygen atmosphere it only takes 0.2 volt to produce a loss of weight that it takes 0.7 volt to produce under nitrogen, or 0.8 volt if the oxygen dissolved in the solution has been displaced by nitrogen.

Partially submerged specimens (Fig. 3) show a very much greater loss of weight as the applied voltage is increased under an atmosphere of oxygen, than do the totally submerged specimens of Fig. 2. That is, when the specimen extends to the top of the solution and oxygen is present, there is a concentration cell which sets up a parasitic current. Under nitrogen the partly submerged specimen behaved like the totally submerged one.

Fig. 4 shows results for various conditions as to oxygen in the solution that can occur with different methods of carrying out the accelerated electrolytic test in the laboratory atmosphere.

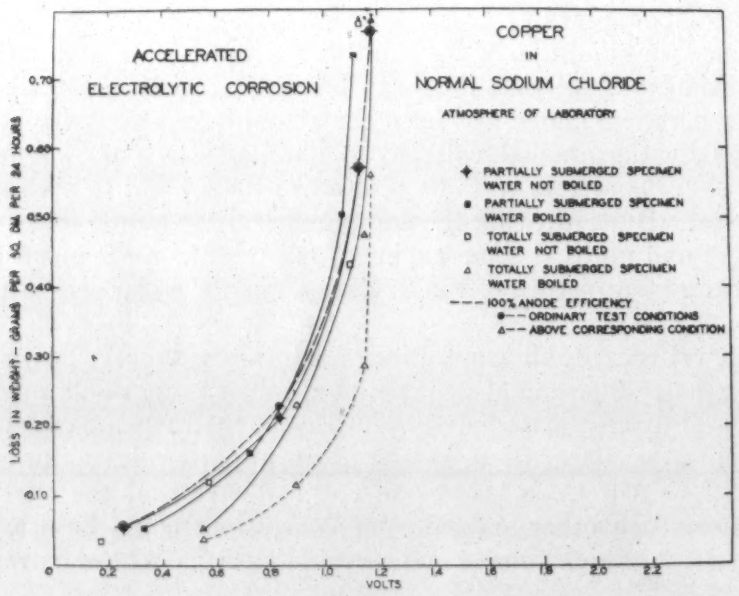


Fig. 4

While the differences are not as great as between the extremes of oxygen-free solution under nitrogen and of oxygen-containing solution under an oxygen atmosphere shown in previous figures, yet they are large enough to show that the oxygen content must be controlled if reproducible accelerated electrolytic tests are to be made.

Similar curves for nickel are given in the original paper and lead to about the same conclusions as to the influence of oxygen.

The electrolytic corrosion curves have to be studied to reveal what they are capable of showing, and they must be curves taken over a range of applied voltages, not single points determined at some arbitrarily chosen single current density. Yet, when such curves are plotted and studied, they do reveal a good deal about the corrosion phenomena that is taking place.

The paper certainly emphasizes the necessity of avoiding uncontrollable oxygen concentration cells in electrolytic studies of corrosion.—H. W. GILLETT.

Report of Meeting of Washington-Baltimore Chapter, A. S. S. T. October 18, 1929

The first fall meeting of the Washington-Baltimore chapter was held at the Commerce Building in Washington on Friday evening, October 18th. The usual dinner preceding the technical meeting was served at the Cosmos Club. Mr. G. M. Eaton, associated with the Molybdenum Corporation of America, the speaker of the evening, presented a talk on "Some Thermal Critical Cycles."

His address was divided into two phases of current metallurgical problems and was presented in an interesting manner, practical examples with their theoretical considerations aided in conveying the speaker's thoughts.

The first phase of his discussion dealt with typical shop problems encountered in the production machining of cast iron; the demands for production work have called heavily on the metallurgist with a slackening of pace on the part of the designing engineer. This point was illustrated by slides, showing how simple designs of patterns could be changed to eliminate machining difficulties due to the formation of white iron (chill effect) by removing the fins from the corners.

The second part of the talk dealt with the dilatation of alloy steel during quenching and consisted of a plea for more cooperation by metallurgists to produce a better surface condition on alloy steels so as to give material of higher fatigue resistance without the necessity of removing the surface prior to heat treatment. Numerous examples and illustrations were given where the resistance to fatigue failure of alloy steels were inferior to similar parts made of heat treated plain carbon steel. Particular mention was made of helical springs designed for heavy work such as used in railroad construction.

The theory back of the observed phenomena is that of martensitic dilatation aggravating transient plastic flow. The transient plastic flow during quenching is the mechanism which creates residual internal stresses in the steel. When the rolled surface of the steel is not machined off prior to quenching this transient plastic flow is severely localized in weak streaks in the surface material, resulting in decreased resistance to fatigue over the "as produced" or "as normalized" material.

Emphasis was placed on the need of industry for alloy steels in which the quality of the surface material of the rolled bar is improved to the point where it bears the same ratio to core characteristics that exist in carbon steels. The engineer, instead of taking the published data as the gospel truth, should know more of the metallurgical considerations back of his design so as to realize the fullest properties of alloy steel.

The members participated in a lively discussion of the various phases of the talk, after which a rising vote of thanks was given Mr. Eaton.—L. J. WALDRON.

Timothy Lydon, formerly general manager for E. E. Steiner & Co., Newark, N. J., before that associated with Young Brothers Co. of Detroit, is one of the principals of Lydon Brothers, a new firm, entering the industrial oven field with headquarters at 229 Colden St., Jersey City, N. J. One of their first developments is a special type of electric heat treating oven.

Merger of Welding Machine Companies

A consolidation of the Thomson Electric Welding Company of Lynn, Massachusetts, and the Gibb Welding Machines Company of Bay City, Michigan, has been announced, the new company to be known as the Thomson-Gibb Electric Welding Company. Both plants will continue in operation.

The Thomson Company is the pioneer resistance welding company having been formed in 1886 to exploit the basis resistance welding patents of Professor Elihu Thomson of Lynn, Massachusetts. Professor Thomson has always been an officer and Director of the Thomson Company and will continue with the new company in both capacities.

The Gibb Company has been one of the most active of the Western companies and has specialized in seam welding.

The Thomson-Gibb Electric Welding Company offer a full line of butt, flash, seam, spot, projection and wire fabric welders together with expert service designed to secure uninterrupted production and uniform quality from its machines in the hands of manufacturers.

Correlated Abstracts

Dr. Gillett, the editorial staff and specially selected contributors will prepare abstracts reviewing the work recently reported pertaining to certain subjects. These reviews will take into consideration the work of a number of workers. The current literature will be covered in the Abstracts of Current Metallurgical Literature.

The Physical Chemistry of Steel-making

The third open meeting of the Metallurgical Advisory Board to the Carnegie Institute of Technology and the United States Bureau of Mines, held in Pittsburgh on October 18th, was attended by about two hundred and fifty metallurgists, operating men and executives from numerous steel companies and was marked by the submittal of The Tenth Progress Report on the Physical Chemistry of Steel-Making by Doctor C. H. Herty, Jr., and his associates. The investigations which were the subject of this and former reports were begun in 1926 under Doctor Herty's able leadership and are being continued on the basis of a 5-year research program. The particular mode of cooperation between industry, education and government which made this program possible is too well known to require explanation here. In fact, the published record of progress has been and is being watched with much interest not only in this country but in Europe as well.

In continuation of studies on the distribution of iron oxide between slag and metal, results have now been obtained on solubility under slags consisting of FeO and MnO and under slags containing P_2O_5. This work has been conducted by J. M. Gaines, Jr., G. L. Frear, H. Freeman and W. O. Krebs and will be described in a cooperative bulletin. In addition to these new solubility relationships, this bulletin will contain a new determination of the equilibrium constant for the reaction between manganese and iron oxide. This redetermined constant checks very closely with one previously obtained by Doctor Herty and his associates from a study of equilibrium in the basic open-hearth furnace. Mr. G. R. Fitterer has completed an investigation on the formation and identification of inclusions coming within the binary system $FeO–Al_2O_3$, such as are formed upon deoxidation with aluminum. Manuscript containing a description of this particular work has been submitted for publication as a cooperative bulletin. This bulletin includes data on the melting points of $FeO-Al_2O_3$ slags, the results of a microscopic study of $FeO-Al_2O_3$ inclusions in steel, as well as data on the deoxidation constant obtained both by experiment and by thermodynamic calculation. Mr. Fitterer with the assistance of J. E. Conley and B. N. Daniloff has also begun a similar study of inclusions belonging to the system FeO–MnO, and with the assistance of M. F. Judkins, another similar study of inclusions belonging to the ternary system $FeO–MnO–Al_2O_3$.

One phase of the recent work at Pittsburgh on which Doctor Herty placed much emphasis has to do with a new method for determining globular silicates in cast steel and in ingots. This method was developed in the course of a study by C. F. Christopher on deoxidation with silicon in the basic open-hearth process. Briefly, the method consists in a visual count of the number of silicate inclusions which occur in a known area on a polished specimen and, by means of a micrometer eye-piece, in the measurement of the diameter of each such silicate inclusion. In this manner the total volume of the counted inclusions may be calculated and from this calculated value, together with data on density, the total percentage weight of inclusions may be obtained. It is stated that this method is extremely accurate and has been checked on specimens of known silicate content. Among other things, the inclusion count method corroborates and amplifies the conclusions of previous Progress Reports on the behavior of silicon in the open hearth. For instance, the inclusion count method shows that the Dickenson method gives low results on high-iron and on high-manganese silicates. It has also made possible the calculation of the FeO content of the bath prior to the silicon addition and has shown conclusively that the method of taking tests from the open-hearth furnace, without any added deoxidizers, always gives low results on FeO content on account of the reaction between carbon and FeO during solidification.

As a result of this particular investigation, it has been concluded that the FeO content of liquid steel is connected very closely with slag composition, temperature and slag viscosity; and, furthermore, that under certain conditions the FeO content is probably controlled to a certain extent by the carbon content of the metal bath. This conclusion is directly at variance with a former conclusion on this subject as outlined in Cooperative Bulletins, 34 (1927) and 36 (1928). The conclusion which had been formerly reached by Doctor Herty and his associates was that the FeO content of liquid steel depended upon and was determined exclusively by temperature and the carbon content of the metal bath. As Doctor Herty took occasion to explain in his presentation of the Report, this change in viewpoint will necessitate a reorientation of certain important subject-matter contained in previously published reports.

Observations on the segregations of non-metallic inclusions in ingots by means of the Dickenson method and by the inclusion count method are under way. This work is being carried on by J. E. Jacobs.

Messrs. Christopher and Jacobs are jointly investigating the important question of the effect of non-metallic inclusions on the rolling properties, surface condition and physical properties of the finished steel. Seamless tube steel has been selected as the first material for this investigation. A total of forty-one heats are being examined and the analytical work, including Dickenson extractions, have been practically completed. Tensile tests have also been completed on both longitudinal and transverse specimens.

The important problem of determining the equilibrium between carbon and iron oxide in iron is being investigated by Messrs. Frear, Freeman and M. W. Lightner. The analytical procedure which is being followed here is designated as a modified Dickenson method. Briefly, it consists in killing the steel in a sample spoon with a large excess of aluminum and determining the alumina in the sample by Dickenson extraction. Interesting data are promised for the next Progress Report. Among other problems which are in progress may be mentioned: (1) reboiling with spiegel in the basic open hearth; (2) the manufacture of ferromanganese in the electric furnace from low-grade manganiferous ores; (3) methods of measuring temperatures of liquid steel; and (4) the viscosity of open-hearth slag.

A new cooperative bulletin dealing with one of the problems in the physical chemistry of steel-making was released at the time of the meeting. This was bulletin 44 and is entitled "Theoretical Considerations in the Analytic Determination of Non-Metallic Inclusions in Steel," by C. H. Herty, Jr., G. R. Fitterer and W. E. Marshall, Jr. The conclusions reached are summarized as follows: (1) none of the aqueous extraction methods proposed and used to date will quantitatively recover any inclusions containing MnO; (2) inclusions extracted by electrolytic means are contaminated by atmospheric oxidation, liberation of hydrogen, metallic iron and porous cup material.

Discussions of Doctor Herty's report on the physical chemistry of steel-making were presented from the floor by the following: Dr. John Johnston, Director, Department of Research and Technology, United States Steel Corporation; Dr. G. B. Waterhouse, Professor of Metallurgy, Massachusetts Institute of Technology; Mr. G. D. Tranter, Open-Hearth Superintendent, American Rolling Mill Company; Mr. H. B. Hubbard, Superintendent, Open-Hearth Department, Inland Steel Company; Mr. R. J. Wysor, General Manager, Jones & Laughlin Steel Corporation; and Mr. A. L. Feild, Research Engineer, Simonds Saw & Steel Company.

In order to visualize the significance and practical importance of the work at Pittsburgh since its inception three years ago, it is first necessary to correlate the new knowledge for which it is responsible with our previous knowledge in this field and at the same time to point out how such new knowledge has reacted on and been influenced by the work of other contemporaneous investigators. Before attempting to do this, however, it should be pointed out that the subject of the Physical Chemistry of Steel-Making has largely resolved itself in the course of the cooperative program into a

question of the formation, occurrence and elimination of non-metallic inclusions during refining and over the entire period prior to the solidification of the ingot. It is almost universally true that non-metallic inclusions are related in some way to the percentage of iron oxide which is present in solution in the liquid steel. Hence, the great emphasis on the percentage of dissolved FeO in what follows. Furthermore, the unsettled state in which our present knowledge of this complex subject remains is clearly exemplified by the above-mentioned Progress Report itself. For example, it is stated in this Report that the FeO content of liquid steel is much higher than Doctor Herty and his associates have heretofore supposed. No suggestion as to how much higher is made, but data are promised for the next Progress Report.

Physical chemistry, like its related sciences, is known both in the theoretical and applied aspects. From its theoretical aspect physical chemistry should contribute to steel making the element of predictability. Applied physical chemistry should enter into the problem both as an instrument for measuring and evaluating significant factors in the steel-making process as it exists to-day and in bringing about improvements in its technique where possible. Here, as elsewhere, it has been difficult to exclude completely the theoretical from the practical or applied and, as a result, development of our knowledge has progressed through a mixture of both.

The question of the FeO content of liquid steel is a crucial one for the reasons already given. There are, broadly speaking, two methods by which this problem may be attacked. First, there is the direct method of determining the FeO content of quickly cooled samples by some method of chemical analysis. Up to the present time, however, no method has been devised which will differentiate between the FeO which was in solution in the liquid steel and that which was in suspension in the form of insoluble silicate and oxide mixtures. On the other hand, it is obvious that reasonably accurate data can be obtained by this method for the particular case where the molten steel is a solution of FeO in substantially pure iron. The accuracy of this direct analytical method increases, of course, as the percentage of dissolved FeO increases, other conditions remaining the same. This direct analytical method was used, for instance, by the British investigators, Tritton and Hanson[1] in 1924 in their very careful determination of the solubility of FeO in pure iron at a temperature slightly above the melting point of the latter. The same method was used over a range of temperatures by Doctor Herty and his associates, who published the results of these solubility determinations in *Cooperative Bulletin*, **34** (1927). Data from these two sources, where comparable, were in close agreement. It is believed, therefore, that the solubility relationships of FeO in pure liquid iron are known with satisfactory accuracy.

The solubility work at Pittsburgh, however, has not only covered a wide range of temperatures, as against a single temperature in the case of the British investigation, but has also proved experimentally that the saturation value of FeO in liquid steel is directly proportional to the FeO content of the slag. Feild[2] had assumed such a linear distribution relationship in his paper before the Faraday Society in 1925 but offered no experimental proof. Experimental proof of this fact has made possible the calculation of the saturation percentage of FeO in liquid steel under a basic slag of any given content in iron oxide.

It is again to be emphasized that in these cases where the direct method of chemical analysis for dissolved FeO has been successfully employed the liquid steel has been substantially free from silicon and manganese, as well as silicates and manganese oxide; the percentage of dissolved FeO has been relatively high; and equilibrium has obtained between metal and supernatant slag or molten FeO. Furthermore, the carbon content of the steel has been either nil or else so exceedingly low as to preclude any evolution of CO. These considerations would appear to exclude the direct method from any application to steel samples taken from the furnace or the ladle, so long as the purpose of the method is to determine the percentage of FeO which exists in solution in the liquid steel, *unless* the method distinguishes between FeO as such and FeO existing in admixture with MnO, SiO_2 and Al_2O_3.

Faced with the difficulty of determining the FeO content of liquid steel sampled during refining or from the ladle, investigators have resorted to various means for the determination of the total oxygen content and of the total weight of non-metallic inclusions,—in the first case by the vacuum tube method developed by Jordan at the Bureau of Standards, and in the second case by extraction methods, such as that of Dickenson, whereby the non-metallic inclusions are separated with varying degrees of success from the metallic matrix. Investigations based solely on the employment of these methods have yielded important practical results. They have not, however, been yet perfected to the point where reliable determinations can be made on any given sample of steel. Furthermore, the data which has been accumulated in this manner can not be readily analyzed to yield reliable information on the dissolved FeO content of liquid steel, regardless of whether determinations are made prior or subsequent to the deoxidizing additions of silicon or manganese, or both. In fully killed steels containing inclusions of the glassy silicate type or inclusions of alumina, the Dickenson method has been shown by Doctor Herty and his associates to yield reliable data on total quantity of non-metallic inclusions. Chemical analysis and microscopic examination of inclusions extracted by Dickenson method from such steels enable a fair estimate to be made of the average chemical composition and the range of compositions exhibited by the non-metallics present. In such steels, however, the percentage of dissolved FeO is certainly too small to permit of estimation.

The second method of attack upon the problem of the percentage of dissolved FeO in liquid steel consists in calculating this percentage from known experimental data by means of physico-chemical theory. It is interesting here to note that this method was first used not so much for the sake of obtaining useful data on steel-making as for the purpose of showing how physico-chemical theory could be applied to industrial processes. The men who first thus applied theory were, in fact, those who were largely responsible for the development of the theory itself, namely, Bodlander and LeChatelier. In view of the experimental data at their disposal, their attempts to calculate the FeO content of liquid steel were of a rather formal nature. Both of these scientists realized that, for the particular case where carbon and dissolved FeO were in equilibrium in molten steel, thermodynamics might be applied. Bodlander[3] for instance, in 1902 took for the solubility of FeO a value of 1.1% at 1500° C., a figure given by Ledebur for the FeO content of overblown converter metal. For the solubility of carbon in iron at this same temperature, he took a value of 7%. Employing the Nernst heat theorem to calculate the free energy of dissociation of CO and of FeO, he obtained an equation for the free energy of the reaction $C + FeO = Fe + CO$. This free energy equation, when converted into terms of equilibrium in molten steel at 1 at. pressure of CO, corresponds to an equilibrium constant (percent C times percent FeO) of 0.00041 at 1500° C. LeChatelier[4] in 1912 and Styri[5] in 1923 went through this same general method of calculation with the help of more complete yet wholly inadequate data. LeChatelier's value for the equilibrium constant was 0.009 at 1600° C. and Styri's value 0.00049 at 1600° C. Even in the case of the most recent of these calculations, namely, that by Styri in 1923, the known probable error involved in the calculated values was so great that little or no importance could be attached thereto from the standpoint of practical steel making.

Among those who made important contributions to this method of attack was McCance[6], whose two papers before the Faraday Society, the first in 1919 and the second in 1925, are outstanding. Many of the observations and conclusions which McCance contributed in these papers may now be regarded as common-place and may, in a manner, seem obvious; but at that time they represented distinctly original conceptions expressed in the common parlance of metallurgy. No matter to what degree some of these ideas may have been previously conceived by a physical chemist such as LeChatelier, for instance, the fact remains that LeChatelier did not give them adequate expression whereas McCance did. Carbon elimination in the basic open hearth, as pictured by McCance in 1919, remains essentially the picture which we have before us to-day, so far as its general mechanism is concerned. Unfortunately, however, the detailed physico-chemical treatment followed by McCrane, in spite of its originality, would seem to be based on an erroneous application of theory, at least in the case of the relation between carbon and FeO. It would seem to have been his idea that the FeO dissolved in liquid steel is determined by the FeO content of the slag and temperature without being affected by carbon content or rate of carbon drop. In 1925, Feild[2] in a paper also presented before the Faraday Society undertook a physico-chemical treatment of the kinetics of carbon removal. He assumed among other things a linear distribution relationship between FeO and the slag and in the metal at equilibrium, and also the

[1] Tritton and Hanson, *Journal Iron & Steel Inst.*, **109**, 90 (1924).
[2] A. L. Feild, *Trans. Faraday Soc.*, **21**, 255 (1925).
[3] G. Bodlander, *Zeit. Elektrochem.*, **8**, 833 (1902)
[4] H. LeChatelier, *Rev. Met.*, **9**, 509 (1912).
[5] H. Styri, *Journal Iron & Steel Inst.*, **108**, 189 (1923).
[6] A. McCance, *Trans. Faraday Soc.*, **14**, 213 (1919); **21**, 176 (1925).

constancy of the carbon-FeO product during refining as well as at equilibrium. He assigned a value of 0.0086 to this equilibrium constant at 1500° C. but it would appear that both the published data and the method of calculation were subject to error. The nature of these errors has been discussed in detail by Feild in his subsequent paper to be referred to later.

In February, 1926, Doctor Herty presented before the American Institute of Mining and Metallurgical Engineers his important paper on "Chemical Equilibrium of Manganese, Carbon and Phosphorus in the Basic Open-Hearth Process." Considering only the matter of the carbon-FeO equilibrium, it was his conclusion that this equilibrium was reached for practical purposes at the conclusion of certain heats where the rate of carbon drop becomes almost negligibly small; and also during the lime boil when there is violent stirring and intimate contact between slag and metal. Analytical determinations of carbon and FeO in steel samples taken at such periods yielded data for the calculation of the equilibrium constant. The calculated values, based on weight percentages of carbon and FeO and on a CO pressure of 1 at., ranged from 0.044 at 1524° C. to 0.021 at 1660° C. These calculated values were considerably lower than his experimentally determined value of 0.05 at 1480–1535° C., which Doctor Herty cites in this paper. In 1927 Doctor Herty and his associates published their first co-operative bulletin which was entitled, "The Physical Chemistry of Steel-Making; The Solubility of Iron Oxide in Iron" (Bulletin 34). In this bulletin the equilibrium data which were obtained by Doctor Herty prior to the beginning of the work in Pittsburgh were again published. However, instead of the conclusion that the carbon-FeO equilibrium is reached only at the end of a heat where the rate of carbon drop is very low and during a lime boil, it was assumed in this bulletin that equilibrium was obtained at all times in the metal bath and was determined entirely by temperature and carbon content—an assumption which Feild had employed in 1925.

From the date of this particular publication (1926) until September, 1929, when Kinzel and Egan presented their brilliant paper on the direct experimental determination of the equilibrium constant, the question of what value should be assigned to this constant remained rather controversial. In a paper which Feild presented before the American Institute of Mining and Metallurgical Engineers in February, 1928 entitled, "Rate of Carbon Elimination and Degree of Oxidation of the Metal Bath in Basic Open-Hearth Practice," several general differential equations were derived which purported to show the relationship between rate of carbon drop on the one hand and, on the other, a number of factors such as carbon content, percentage of dissolved FeO, slag composition, depth of metal bath and temperature. On the basis of these equations and open-hearth data previously published by Keats and Herty, it was argued that the FeO content of liquid steel was in all cases affected by rate of carbon drop and that the percentage of dissolved FeO in the steel bath during refining might well be several times as high as would be calculated on the assumption of carbon-FeO equilibrium. A purely tentative value of 0.0102 was assigned to the equilibrium constant at 1580° C., as against a calculated value of approximately 0.034 given by Herty and his associates. In a subsequent publication (Bulletin 36), "The Physical Chemistry of Steel-Making: Deoxidation with Silicon and the Formation of Ferrous and Silicate Inclusions in Steel" (1928), Herty and Fitterer employed a recalculated equilibrium constant of 0.016 at 1580° C. The paper by Feild was the subject of considerable discussion, both favorable and adverse. The mathematical treatment was generally accepted, except by Styri. The chief point in controversy would seem to have been the matter of the proper value for the carbon-FeO equilibrium constant. Since no reliable experimental determination of this constant had at that date been made, no particular advance could be made beyond the theoretical equations which were admittedly of a general nature.

It was at this time that A. B. Kinzel and J. J. Egan, working at the Union Carbide and Carbon Research Laboratories, made direct measurements on the carbon-FeO equilibrium in molten iron under a CO pressure of 1 at. Their measurements seem to have been of a relatively high order of accuracy and indicate a value for the equilibrium constant of approximately 0.0005 at 1550° C. This work was described in a paper presented before the American Institute of Mining and Metallurgical Engineers at Cleveland in September, 1929, although a preliminary report setting forth the essential findings was given by the authors at the meeting of the Institute in February, 1929.

Because of the exceedingly low value for the equilibrium constant as experimentally determined by Kinzel and Egan, it has been necessary to reconstruct many ideas regarding the significance of the FeO content of liquid steel and of the apparent slag-metal equilibrium which is about reached at the end of some heats. Recalculation of the equilibrium constant from reasonably reliable data without recourse to the Nernst heat theorem has served to corroborate the essential correctness of these experimental values.

It would now appear that liquid steel during refining contains much more dissolved FeO than would correspond to equilibrium—a conclusion which was forecast by Feild. At the same time, it would also appear that the percentage of dissolved FeO in a steel bath substantially at equilibrium with the slag is generally much higher than would be predicted from this new equilibrium value. It need hardly be said in conclusion that the entire question of the percentage of dissolved FeO in liquid steel remains unanswered and that the application of theoretical principles must be carried further before a clear understanding of open-hearth refining is reached.—Alex L. Feild.

A Zinc-containing Lubricant for the Prevention of Corrosion

In the Sept. 27, 1929, page 337, issue of *The Engineer* (London) is an account of an interesting case of corrosion and its solution which is worthy of rather careful consideration. The "Keenok" pinion is a device consisting of a hardened steel tire and a central member, both of which are serrated to receive between them a number of hardened steel rollers. End plates are attached to the central member to retain the rollers and the tire in position. The tire has a freedom of one or two thousands of an inch on the ring of rollers. The central member is splined for attachment to a shaft. The pinion may be used in several ways. In the instance given it is used for the transmission of power between two parallel shafts. The tire of the pinion presses against a plain collar on the second shaft. The pressure between the two sets the tire slightly eccentric to the inner member of the pinion. The tangential force received by the rollers from the tire causes the rollers on the contact side of the pinion to move slightly up the slopes of the serrations in the tire and inner member. By so doing, they act to restore the tire to concentricity with the inner member and therefore to increase the contact pressure between the tire and the driving—or driven—shaft. The greater the tangential force applied to the tire and therefore to the rollers, the further will the rollers climb up the serrations, and consequently the greater will be the contact pressure between the tire and the driving shaft. The correlation between the contact pressure and the tangential driving force on the tire is so complete that at all loadings no slip occurs between the driving and driven shafts, even when, as is the normal practice, the whole gear is run in the presence of a lubricant. The tires and the rollers are therefore subjected to very severe and rapidly alternating stresses. Severe "corrosion" was encountered whether the pinion was run dry or with lubricants. In the experiments carried out, using a fixed-ratio gear box, the pinion was run at speeds from 500 to 5000 r. p. m. and some high-speed tests up to 40,000 r. p. m. were made. "Corrosion" increased as the load increased and the speed became higher.

With oil as a lubricant, marked "corrosion" was set up at certain points, particularly where adequate circulation of the oil could not be maintained. Most of the working parts were, however, satisfactorily protected, but the employment of oil as a means of preventing "corrosion," even though it had been completely satisfactory, was not practicable, because it was found difficult to prevent its leaking from the gear case. It was therefore decided to use grease as the lubricant, for it was hoped that while it would give the protection afforded by oil, it would overcome the difficulty caused by leakage.

When the gear-box was packed with grease, every working part, it was immediately found, was subject to violent "corrosion."

After a short run the friction surfaces of the pinion and shaft, the shaft seatings, and the roller bearings in which the shafts were supported were ruinously "corroded," the surfaces in some cases being eaten away by as much as 1/64 inch. The "corrosion" did not occur only at those portions of the gear which were called upon to withstand abrasive action, but also at the seating of the pinion on the shaft and other tightly fitting parts. Originally, the pinion was a tight push fit on the shaft, and was keyed to it in the usual way. After a run of only 300 hours, the seating on the shaft had been reduced in diameter by nearly 1/64 inch, the keyway had become badly eaten away on one side and about one-third of the metal of the key had disappeared.

It was observed that there was a distinct difference between the "corrosion" occurring at the seatings of the shafts and that taking place on the surfaces possessing rolling motion. The seatings were rough and appeared as if they had been etched with a strong acid. The surfaces having rolling motion were "corroded" to a smooth glassy finish, and were stained reddish-brown. On analyzing the grease, it was found that its acidity had increased, and that it contained a large percentage of iron oxide.

Tests of various greases were made, the inside of the gear box itself being enameled white to prevent any effect of the cast iron case. In every instance serious corrosion resulted. Iron oxide was found sprayed evenly over the enameled surface, and could be wiped off as an impalpable red dust. Cadmium plating soon oxidized and left the steel exposed. Chromium plating of sufficient thickness interferred with the dimensional accuracy of the gears.

It was finally found that if 50% or more zinc oxide was added to the grease, the parts at which corrosion previously occurred were plated with a film of metallic zinc and no further trouble with corrosion was encountered. This film was reported by the National Physical Laboratory to be metallic zinc and of a thinness invisible under the microscope when viewed transversely. By analyzing the coating and calculating the thickness, it was found that it was of the order of 0.0004 mm. It should also be noted that the film was not formed if the surfaces in contact were of non-ferrous metals or alloys and was present only in the case of steels and iron.

The explanation offered by the investigators was as follows. When two metal surfaces are brought together suddenly under pressure, an electric stress is produced at and around the point of contact. The origin of this electric stress may be traced to the fact that the pressure develops heat and, as a consequence, thermo-electric phenomena may be expected to occur. As an alternative or supplementary source of the electric stress, it is observed that magnetic effects, as is well known, cause slight alterations to take place in the dimensions of iron specimens. It seems, therefore, legitimate to argue that the converse will hold good, namely, that slight alterations in the dimensions of a specimen of iron will give rise to magnetic effects. This aspect of the subject has not so far attracted much attention from research workers. Whatever be the cause of the electric stress, the fact that it is manifested is regarded as definitely established. The surfaces under direct pressure are held to acquire a charge of negative electricity while neighboring surfaces are charged positively. In most cases these charges disappear almost immediately by conduction through the metal. If, however, the action is repeated continuously, an alternating electric stress is produced and the surfaces become alternately positive and negative. If the periodicity of the application of the pressure is high—as, for example, in parts rolling rapidly under pressure—considerable differences of electric potential may, it is held, occur. In many forms of running machinery these conditions for the establishment of surface differences of potential exist. It, therefore, only requires the presence of a suitable electrolyte to set up the electrolytic corrosion of the surfaces. Such an electrolyte, it is contended, is commonly provided by moisture or impurities in the air or by the lubricant, if one is used. Further investigation at a constant pressure of 450 lbs./sq. in. showed no potential difference until the frequency reached 60 per second. The potential then gradually increased to a value of 0.145 volts at a frequency of 180. The explanation of the deposition of the metallic zinc film is held to be one of deoxidation of the zinc oxide, the deposition of metallic zinc on the steel parts under load, and the oxidation of the zinc back into zinc oxide thus maintaining a film of constant thickness or thinness which does not interfere with the dimensions of the parts and which, once formed, does not increase in thickness. It was also observed that the surfaces instead of being softened by the film of zinc are, after a period of continuous running, noticeably harder than they were before the steel was coated with zinc.

These are the salient facts and the explanation as given by the investigators. The corrosion of steel in tight contact and with no electrolyte other than the moisture and oxygen of the air has been reported before, notably by Eden, Rose and Cunningham. (*Proc. Inst. Mech. Eng.*, 75, 875 (1911)). They reported that in endurance testing a considerable amount of trouble was caused by corrosion where the test specimen fitted into its holders. The rusting at this point was so great in the case of heavily loaded tests, lasting for several days that it was often difficult to remove the broken specimen from the holder. This observation was followed by a discussion carried on in *The Engineer* in which other instances of this type of corrosion were reported and various and ingenious explanations offered. (*The Engineer*, **112**, 542, 572, 597 (1911)). In 1927, G. A. Tomlinson, *Proc. Roy. Soc.* (*Lon.*), **A115**, 472–83 (1927), took up the question and carried out some very extensive experiments which seem to have been overlooked by the present investigators and which also seem to be made to order for this particular problem. He placed a spherical and a plane surface under pressure in relative motion at their common point of contact, the motion in some cases being a rotation about the common normal and in others a tangential sliding motion. Table 1 gives his results and his comments on his experiments.

"In Experiment A no rusting was produced and as the surfaces were only cleaned in a mechanical way by careful wiping, it is most probable that a persistent primary film remained and completely separated the metal surfaces." Increasing the pressure to seven times that of A resulted in considerable oxidation.

"Experiment D is of considerable interest. A load of only 0.23 grams on a comparatively large sphere was found to produce the typical oxidation debris to quite a marked extent when the surfaces were well washed with the cleaning fluid and the primary film was presumably removed. This experiment disposes of one possible explanation of the rusting which might be suggested by ordinary observation of the phenomenon as it occurs in practice when lapped surfaces are found to rust on being rubbed together. This explanation is that the surfaces, which on a minute scale are completely scored by the lapping abrasive, are crushed together under a heavy normal stress and a fine powder is thus produced by a mutual grinding action, the powder oxidizing to form the well-known stain. In this experiment the surfaces are both highly polished and no scratches at all are visible under the microscope. The mean contact stress is only 5,000 lb./sq. in. whereas Experiment C shows that similar surfaces can bear a normal stress as high as 354,000 lb./sq.in. without any injury visible under the microscope. It thus seems most improbable that in this case the oxidation is the result of any such coarse abrasive action between the surfaces. Experiment F also strongly confirms this view, as here the spherical surface is a fused bead which is comparable in texture with a fluid surface and certainly will have no prominences such as are necessary for abrasion to take place.

"Experiment C shows that no oxidation occurs unless there is relative tangential motion of the surfaces even under excessive intensity of normal stress. Hence, the effect is not due to the local application of heavy pressure which might conceivably set up an electrolytic action. This is further confirmed by Experiment E in which a motion of pure rolling was used, again with a fairly heavy normal stress. This motion produces no oxidation.

"Experiments F, G and H show that the same result follows from the sliding contact of glass, stellite and agate, in all cases with comparatively small contact stresses."

Tomlinson's idea is that it is a result of atomic cohesion. When two solids touch, the forces between the atoms or at least some of the atoms are sufficiently great to cause the atom to be detached by a lateral movement. The attraction of an atom in one solid for an atom in another solid is, of course, less than the attraction of two atoms in the same solid. Experiment E, in which the motion is one of pure rolling and in which the relative motion is always exactly normal to both surfaces, shows this. The nature of the interatomic force appears to be such that the cohesive force of a visiting atom is quite insufficient to pluck the atom out normally, but is sufficient to detach it from the solid when applied tangentially. This suggests the view that the boundary atoms, by virtue of their unsymmetrical position, have a considerable degree of orientation, so that an external tangential force is able to disturb the initial equilibrium so much that individual atoms as distinct from finite particles can be wrenched away. The atoms so detached combine very quickly with oxygen molecules from the atmosphere. This would explain how "corrosion" could occur in tightly jointed high speed machines. Although apparently immovably fastened together, actually there would probably be a minute to and fro movement.

Table I

Nature of Surfaces	Diameter of Sphere	Load Gm.	Mean Intensity of Pressure Lb./Sq. In.	Motion Applied	Result
A. New Hoffmann ball on lapped slip. Cleaned mechanically	0.344	25	30,000	Rotation about common normal	No visible effect
B. Hoffmann ball on soft steel plate. Cleaned mechanically	0.344	213	61,000	Rotation about common normal	Surface much torn up but no oxidation color to be seen
C. Hoffmann ball on lapped hard steel. Cleaned mechanically	0.0325	368	354,000	No motion. Load left on for 40 hrs.	No effect
D. Hoffmann ball highly polished on hard steel highly polished. Surfaces cleaned chemically	0.469	0.23	5,000	To and fro about 100 times	Considerable brownish debris, partly spread on the surface and partly swept up at the ends of the track. The latter could be wiped away
E. Two polished Hoffmann balls on polished hard steel. Cleaned chemically	0.14	1.80 per ball	106,000	Pure rolling to and fro 8000 complete oscillations.	No effect
F. Fused glass sphere on polished steel. Cleaned chemically	0.25	4.6	12,500	To and fro about 100 times	Considerable amount of oxidation residue of reddish color. Cannot be removed by repeated wiping
G. Polished stellite sphere on polished steel. Cleaned chemically	0.16	12.3	40,000 (approx.)	Tangential motion in small circles	Typical brown debris produced. Visible with the naked eye
H. Polished agate sphere on polished steel. Cleaned chemically	0.16	2.3	..	To and fro about 150 times	Considerable oxidation produced
J. Polished steel sphere on polished steel surface smeared with vaseline	0.14	12.3	43,500	Tangential motion in small circles	No effect
K. Polished steel sphere on polished steel surface smeared with vaseline	0.14	110	90,000	Tangential motion in small circles	Marked rings of brown oxidation produced which are permanent after wiping off the vaseline
L. Polished steel sphere on polished steel. Surface smeared with castor oil	0.469	365	60,000	To and fro motion	Usual oxidation debris produced but not continuous along the whole track, mostly at one isolated place
M. Polished steel sphere on polished steel. Surface smeared with castor oil	0.469	45.6	30,000	To and fro motion	No oxidation visible

If, this author states, "we consider electrolysis in the stressed material, this should occur irrespective of any motion of the surfaces, whereas tangential motion was found to be necessary. Furthermore, electrolysis requires an appreciable time, and it was found that a single quick passage of one surface over the other produced rust." From calculations from his experiments he also determines that the rise in temperature must be very minute and that rusting could not be dependent on it.

In the case of the "Keenok" pinion, the relative motion would be almost entirely tangential and at high pressure. Tomlinson's explanation, therefore, seems a much more reasonable explanation than corrosion due to electric potentials.

Considering the zinc oxide lubricant, it is difficult to see how the oxide could be reduced if such reduction depended upon differences of electric potential, particularly when they only amount to about one-tenth of a volt. On the other hand, the dislodging of atoms by high tangential stresses would produce very active atoms which should be capable of reacting with the zinc oxide possibly to form a zinc-iron alloy film on the surface. The tangential stresses could tear down this film as readily as they could dislodge iron atoms and the active dislodged atoms could again form the protective film. The production of potential differences between parts of the pinion could conceivably be due to the electric charges released by the detaching of the atoms and would then be the result rather than the cause of the corrosion. It would be interesting to know if a similar metallic film would be formed if salts of other metals, for example cadmium, were added to the lubricant. The affinity of iron for chromium is probably not sufficient for the successful use of that metal. The hardening of the surface is due to the stressing it has received and not to any action of the protective alloy film.—V. V. KENDALL, Dept. of Metallurgy and Research, National Tube Company, Pittsburgh.

Editor's Note:

It seems to us that a differentiation should be made between ordinary rusting, or corrosion in the presence of air and moisture, and the formation of iron oxide through the mechanism of tearing off particles so fine that they are pyrophoric and at once burn to oxide in the dry way.

We see no reason to believe from the account on the formation of iron oxide in the greased "Keenok" pinion that ordinary rusting took place.

Those who make "dry" wear tests are familiar with the formation of oxide particles, some of which are detached, and some of which adhere as a film, under conditions that make Tomlinson's explanation obviously the proper one. We have seen other cases of minute motion in the grips of a repeated-bending endurance machine where a constant shower of obviously pyrophoric particles were detached.

One wonders also whether the speculations of the article and of the accompanying editorial in *The Engineer* on how the metallic zinc film came to be formed, should not have been preceded by a more thorough proof that it was metallic.

It is true that the report of the National Physical Laboratory categorically states that is a very thin film of zinc, but this seems to be predicted on the observation that the surface *looked* like a buffed surface of a comparatively soft metal. The chemical analysis of the surface reported in terms of zinc, of course, offers no proof whether the zinc found was present as such or as embedded zinc oxide. The examination at the National Physical Laboratory appears to have been on the order of a routine test rather than an exhaustive research. The matter is of some importance, and it would seem that measurements of electrolytic solution potential or some other means that would more definitely prove whether or not the surface was coated with metallic zinc would carry more conviction.

Assuming that a metallic zinc film was present, one wonders why it is necessary to load up the lubricant with zinc oxide and reduce this instead of using zinc directly.

It is stated that the applications for patent on the zinc oxide lubricant have been made in the principal countries.

In this country, oil petrolatum or other grease and zinc dust has long been used as a lubricant for threaded joints, especially in the oil industry, and we understand that there are no patents on it. In fact, the National Tube Company, which worked out the zinc grease in its laboratories some years ago, gives in its booklet, "Plain Facts About Casing, Drill Pipe and Tubing," the actual recipe for making the grease—which reads: "120 lbs. zinc dust, 70 lbs. golden crank pin grease No. 3—10 lbs. (5 quarts) Ball Chemical Company's spraying oil," all mixed in a power-driven machine.

Lead filings and oil serve similarly. These soft metals make a tight joint, avoid contact of the iron and steel surfaces, and hence, prevent cohesion and galling, so that the joint, though tight, can be very readily unscrewed.

There are several interesting theoretical questions involved, such as whether zinc oxide may really be reduced to metal in this way, in which case, there might be possibilities for making zinc dust by some modification of the method, and whether zinc so reduced or zinc added as such can alloy with iron to form a zinc iron alloy without the high temperatures usually supposed to be required. Then there is the practical aspect as to how well zinc dust or zinc oxide greases prevent wear, and which is the better.—H. W. GILLETT.

Abstracts of Current Metallurgical Literature

In this section, abstracts of metallurgical articles in various publications will appear. These abstracts are not critical, but merely review developments as they are recorded. Every effort will be made to report on all articles as soon as possible.

Many laboratories do (and more laboratories would if they appreciated its value) adopt the policy of clipping, pasting on cards and filing abstract literature. In order to help those who wish to do this, additional copies of METALS & ALLOYS *will be sent to any subscriber for $2.00 per copy per year extra. The time required for clipping, pasting and filing is so much less than the time needed to transcribe abstracts that a distinct saving can be made by ordering extra copies.*

PROPERTIES OF NON-FERROUS ALLOYS

Die-Casting Progress in Europe. E. V. PANNELL. Appendix IV to report of subcommittee XV (on die-castings) of Committee B-2 (on non-ferrous metals). Preprint No. 19, *Proceedings American Society Testing Materials*, **29** (1), (1929), 4 pages.

Gives compositions of Al-base and Zn-base die-castings used in England, Germany and France and discusses die-casting test programs of technical associations abroad. HWG

The Composition of the ϵ-Bronze. W. HUME-ROTHERY. *London, Edinburgh and Dublin Philosophical Magazine*, July, 1929, pages 114–121.

Previous investigations are given which are not altogether in accordance. Conflicts between the X-ray and metallographic methods exist. Most of the earlier investigators, however, consider the ϵ-phase to be a definite compound Cu_3Sn of fixed composition. To encounter the discrepancies in terminology: the ϵ-phase is on the copper side in equilibrium with the α-phase up to 580° C. and with the γ-phase from 580–680° C., at which temperature the ϵ-phase decomposes. On the tin side, there is an equilibrium with the η-phase up to 415° and then with the liquids up to 625° C., at which temperature the γ-phase bends over and is in equilibrium with the ϵ-phase on either side. Long annealing times were applied sometimes amounting to 32 days. Equilibrium conditions thus certainly were obtained. From the results of the present investigation it may be concluded that the ϵ-bronze phase is a solid solution of which the limits vary from 24.5 to 25.1 atomic percent tin, any variation of the solid solubility with temperature being within the limits of the experimental methods. This range of composition includes the simple whole number ratio Cu_3Sn and is thus in agreement with recent X-ray crystal analysis. It seems more than probable that the phase in equilibrium with the liquid is the pure compound Cu_3Sn. On the other hand, the work seems to show conclusively that a solid solution exists on the copper side of the compound to an extent of about 0.5 atomic percent. We seem, therefore, to have a real compound in the chemist's sense of the word, corresponding to the existence of a definite molecule, but which can take up small amounts of one of its constitutent elements into solid solution. X-ray examination of this slight solution is suggested. EF

Life Tests on Metallic Resistor Materials for Electrical Heating. F. E. BASH AND J. W. HARSCH. *Preprint No. 50, Proceedings American Society Testing Materials*, **29** (2), (1929). See also Preprint No. 21, Report of Committee B-4 on High Temperature and Electrical Re istance Alloys.

The quality and life of nickel chromium resistor elements for electric furnaces are of interest to the metallurgist who is using electric furnaces more and more for heat treatment. The use of these elements in toasters and similar appliances is of interest to the housewife. So important have the resistors become that the American Society for Testing Materials has established a committee to study methods for testing their durability. As a result of three years' cooperative work, methods of test have been worked out and are described. So far they have been applied only to 20 and 22 gage round wires. For intermittent use, the life of a resistor largely depends on its ability to form and maintain an impervious oxide coating which does not scale off. Since heating and cooling tend to crack off the scale, intermittent heating is used in the accelerated life test proposed as a tentative standard test method. The wire is suspended vertically, held under a stress of 35 lbs./sq. in. by a weight. The lower end dips into a mercury cup. The wire is shielded from drafts, else scale-forming conditions are not uniform, so this is very essential as is close voltage control of the heating current. Test temperatures are 1066° C. (1950° F.) for the 80 Ni, 20 Cr type and 1010° C. (1850° F.) for the 60 Ni, 15 Cr, 25 Fe type and are observed by a disappearing filament optical pyrometer with magnifying objective lens. After setting the current to give the correct temperature, the interrupter is switched in. It is recommended that this be a motor operated vacuum mercury switch. It throws current on and off at 2 minute intervals, this cycle giving the shortest life. The temperature is then readjusted after 3 hrs., 7 hrs. and thereafter every 24 hrs. The time in hours to the point when the current drawn to give the standard temperature drops 10% through increase in resistance of the wire, is a measure of the useful life of the wire, at least for intermittent use. The run is also carried on till the wire burns out. Check tests should agree within ±7.5%. The committee report contains a tentative method for chemical analysis of these alloys for copper and details of the density for determining cross section of the specimen. Label colors for various resistor wires have been agreed upon by manufacturers as follows:

80 Ni 20 Cr	yellow	45 Ni 55 Cu	pink	Pure Ni	green
85 Ni 15 Cr	white	30 Ni 70 Cu	blue	Manganese nickel	salmon pink
Ni-Cr-Fe	red	Ni steel (low Cr)	lavender	Monel metal	orange

Chemical analysis alone is stated to be valueless as an indication of life in service. With the same analysis, the life may vary greatly. Bash and Harsch say "The chemical constituents which reduce the life of a heating element are either present in such small quantities that they are not detected or no analysis is made for them in a standard analysis. We have particularly in mind oxygen or dissolved oxides." This reminds one of the claim of Rohn[1] for improved properties of alloys of this type when vacuum-melted. HWG

[1] Rohn, W. Technische Eigenschaften vakuumgeschmolzener Metalle, *Zeit. für Metallkunde*, **21**, 12 (1929). See also same journal, **18**, 387 (1926), and *Electrotech. Zeit.*, **1927**, pages 227 & 317.

PROPERTIES OF FERROUS ALLOYS

Interim Report on the Density of Molten Steel. (Sec. IV of the Third Report on the Heterogeneity of Steel Ingots.) C. H. DESCH & B. S. SMITH. *Advance copy, British Iron and Steel Institute*, Spring meeting, 1929.

The density of molten steel is to be studied by weighing an alundum cylinder (or one of W coated with alundum) which is weighted so that it sinks in molten steel. Viscosity is also to be determined by a torsional pendulum. This paper describes the methods used. Provisional values for 0.04% C steel at 1530–1560° C. run from 6.8 to 7.05. For 3.10–3.70% carbon iron-carbon alloys at 1300–1465° C., the density runs from 7.15 to 7.30. HWG

CORROSION, EROSION AND PROTECTION OF METALS AND ALLOYS

A Simple Apparatus for Immediate and Direct Reading-off of Corrosion of Metals, of Formation of Incrustation and of the Oxidation Power of Solutions. (Eine einfache apparatur zur sofortigen und direkten ablesung der Korrosion von Metallen, der Inkrustationsibildung, sowie der oxydierenden Kraft von Lösungen. Oxydimeter nach Toedt.) DR. L. KOEHLER. *Chemiker Zeitung*, July 20, 1929, page 567.

Previous methods: gravimetric; new method: measurement of currents. Connecting a rare metal with the metal, which is to be investigated and which can have any size, in the corroding medium (liquid), the current produced by this galvanic element is measured and converted into loss of weight by the law of Faraday. The relationship between oxygen diffusion, current intensity and corrosion is discussed. The equipment which gives corrosion directly in gm./day and $m.^2$ is illustrated and its advantages given. EF

The Distribution and Velocity of the Corrosion of Metals. ULICK R. EVANS. *Journal of Franklin Institute*, July, 1929, pages 45–58.

The present paper summarizes the main conclusions of recent researches on the corrosion and passivity of metals. The first part deals with the distribution of corrosion. The oxide films are compared with those appearing on metals heated in air. Methods of undermining and isolating the films are given, the short anodic treatment in sodium chloride is preferred. The role of oxygen is considered to be necessary for the corrosion, but the attack occurs at places relatively inaccessible to oxygen. The direct effect is to maintain a protective film, its indirect effect is to set up corrosion at the places, where this film is weak and absent. The reactions occurring after vertical immersion of zinc, iron and aluminum into NaCl-solution are compared. Stainless steel (Cr) becomes covered by a highly protective skin. The several conditions which influence the variations in the protective character of different oxides are outlined. The behavior, furthermore, also depends on other conditions, as for instance motion of liquid, supply of dissolved oxygen, inclination of the surface, etc. Distinctions between localized and slow, and general and rapid corrosion are made. The action of "film-repairing" substances are discussed. The principle of choosing a metal which will yield an insoluble body as a direct anodic product is discussed by means of lead (lead sulphate) in contrast with iron (rust). The second part is largely confined to the question of velocity of corrosion. The problems of maximum EMF, polarization, relative size of cathodic and anodic areas, nature of film, concentration of penetrating ions, conductivity of the liquid are the single steps leading to the equations of Bengough, Stuart and Lee. In a diagram potential values are plotted against current, which is proportional to the corrosion rate. With respect to potential, the present knowledge is summarized: (1) The potential drops when the current is drawn off. (2) The highest potentials are obtained under conditions most favorable for oxygen-replenishment. (3) The potential is abnormally low near cut edges or other weak places on the film. Corrosion in oxygen atmosphere is compared with that of air and the effect of alterations in the concentration of the solution is discussed. Results from determinations of corrosion velocity of vertical specimens in closed vessels under thermostatic conditions are reproduced, proving the velocity to be a function of the oxygen supply and of the nature of the metal. EF

Notes on the Wear of Railway Rails. *Iron and Coal Trades Review*, July 26, 1929, page 117.

An abstract of an article by L. Lubinoff in *Revue de Metallurgie* with notes on the wear of steel rails on the Russian railways over a period of 29 years. Observations over the first period of 1889–1904 on 190 rails include: (1) maximum depth of wear of rail head 3.75 mm., or 0.079 mm. per million tons of load; (2) maximum lateral wear of 2.25 mm., or 0.04 mm. per million tons of load; (3) maximum transverse crushing of rail head 3.5 mm., or 0.073 mm. per million tons of load carried. Rails showing very little wear showed limits of: Carbon 0.39–0.77%, Mn 0.13–0.87%, P. 0.04–0.115%. For the second period 1904–1928 records on 90 rails were available. Only 11 rails were found unfit for further service at the end of 29 years, 24 have shown no trace of wear or crushing 42 were crushed on the head from 0.1–0.7 mm. at the joints, and only 10 showed a large amount of crushing, viz., 5–9 mm. WHB

Appearance of Corrosion in Sheets of Aluminum. (Korrosionserschenungen an Al-blechen.) R. WESENBERG. *Chemische Fabrik*, May 1, 1929, page 208.

Attention is called to the influence of suboxide inclusions upon corrosion resistivity of rolled aluminum. EF

The Oxidation of Iron and Steel at High Temperatures. L. B. PFIEL. *Preprint No. 11, British Iron and Steel Institute*, Spring meeting, 1929.

Pfiel's theory of scale formation on heated steel assumes that the scale is not formed from the outside in by diffusion of oxygen only, but that what is, finally, the middle portion of the scale is first formed, and that oxygen diffuses in and metallic iron diffuses out. In nickel steel (2.75% Ni) the outside layer of scale, after heating in free air at 1000° C. till heavy scale had formed, was almost free from Ni. In a 36% Ni, Ni Fe alloy similar results were met, and the inner layer was greatly enriched in nickel. In the Ni steel and the Ni Fe alloy there was marked intercrystalline penetration. With a 12% Cr steel and a 3.2% Ni, 0.85% Cr steel the outer layer of scale was almost free from the alloying elements. A 5.5% W steel showed little W in the outer layer perhaps due to the volatility of WO_3. A 2% Si steel showed no Si in the outer or middle layers. Steels with 0.7% and 3% Mn showed no marked difference in Mn:Fe ratio in the three layers of oxide. Fe will reduce NiO, hence the layer just below the scale, enriched in Ni, tends to remain unoxidized. To this is ascribed the exceptional heat resistance conferred by nickel. Manganese is very soluble in the scale. Metallic Si appears to be insoluble in the scale.

Soft carbon steel bars, slightly oxidized, may become very brittle, while if oxidiation is more severe, embrittlement is less pronounced. HWG

The Erosion of Guns. R. H. GREAVES, H. H. ABRAMS AND S. H. REES. *Advance copy, British Iron and Steel Institute*, Spring meeting 1929, 55 pages.

In opposition to conclusions of various previous investigators who attribute the erosion of guns to surface cracking in a carburized or nitrided surface with resultant tearing off of particles, or to mechanical erosion by gas leakage, Greaves and collaborators conclude that the only primary cause of gun erosion is due to the actual melting of a thin surface layer of the bore and the sweeping away of melted metal by the escaping gas. Surface cracking is not considered a cause of erosion, but as an unimportant by-product. Erosion would not be reduced if cracking were eliminated. The melting point of the metal of which the gun is made, with specific heat, latent heat of fusion and thermal conductivity as minor factors, primarily controls the erosion. Since the other mechanical properties required eliminate higher melting alloys than the usual gun steels all that can be done is to choose a cooler propellant. HWG

STRUCTURE OF METALS AND ALLOYS

Structure and X-Ray Analysis

Some X-Ray Studies of Cold Worked Steel. F. C. ELDER. *Heat Treating and Forging*, June, 1929, Pages 717–720.

Paper before American Iron and Steel Institute. Investigates the changes which take place in the pinhole type X-ray patterns during cold drawing low carbon steel. Presents numerous photographs of wire drawn through a die with various degrees of reduction. These indicate that cold work takes place in two stages. In the first, the crystals are apparently fragmented. This stage extends up to an amount of cold work equivalent to 10–20% reduction in area. The extent of this stage depends chiefly on grain size, i. e., the smaller the grain the sooner the appearance of the preferred orientation, which is characteristic of the second stage. Cold worked structures persist in wires cold drawn 80% even after annealing at fairly high temperatures. In less severely cold drawn wires, evidence of the cold work is removed at comparatively low temperature annealing. MS

On the Relation between the Lattice-Constant and the Density of Solid Solutions. S. SEKITO. *Science Reports, Tohoku Imperial University*, May, 1929, pages 59–68.

The author investigated the lattice-constants of solid solutions of the following alloys: Cu-Al, Cu-Sn, Cu-Fn, Cu-Mn, Cu-Ni. The discrepancy between the density observed and that calculated from the addition law must be ascribed to a change in the lattice constant. GN

X-Ray Investigation of Iron and Nitrogen Alloys. A. OSAWA AND S. FWAIZMUN. *Science Reports, Tohoku Imperial University*, May, 1929, pages 79–89.

The lattice and the lattice constants of the compounds Fe_4N and Fe_2N were determined. Fe_4N is face-centered cubic; 3.86. Å lattice constant, calculated density 6.57. Fe_2N is hexagonal, one nitrogen atom in each elementary parallelopiped lattice, 2.743 lattice constant, Co/Ao = 1.59, calculated density 5.02. Recalculated diameter of the nitrogen atom 1.26 Å, agrees with the value found by Bragg. GN

Appearance of Heat Treatment of Duralumin in the X-Ray Photograph. ("Die Veredelung einer Aluminiumlegierung im Roentgenbild.") FRHR. VON GOELER AND G. SACHS. *Metallwirtscahft*, July 12, 1929, pages 671–680.

The theory of hardening by precipitation is briefly presented and explained by means of the Al-Cu constitutional diagram. Extensive references to previous publications are made. The investigations were performed with Al-alloys containing 5% Cu. The change in mechanical properties of the specimens quenched at 525° C. and heat-treated at various temperatures are reproduced in a diagram showing a maximum and a minimum of favor-

able properties. Investigations up to the present, however, proved that the favorable results occur at temperatures and after tempering times before microscopic and X-ray analysis showed any precipitation. Electrical measurements of conductivity as well as the small tendency of recrystallization of single crystals even contradict the assumption that a precipitation takes place at all in combination with hardening. The reproduced curves indeed indicate more complicated processes than can be explained by the precipitation theory. Thus after short heat-treatments (half an hour) the curve of strength in all cases exhibited two different procedures. In order to reveal the cause of ageing, the change in properties and structure had to be disclosed. Previous investigations proved the difficulties of obtaining marked reflections from the precipitated $CuAl_2$ crystals since only present in relatively small amounts and in extremely fine dispersion. The measurement of such low intensities is avoided by the determination of the constant of atomic distance in the space lattice of the $CuAl_2$ solid solution which is a straight line function of the copper content. The value of this constant and the location of the reflections are consequently varying with the beginning of any precipitation. These values have been checked by Debye-Scherrer photographs on wires containing various Al contents. The successively experimental steps, the data and their computation are fully described and illustrated. An astonishable accuracy of 0.01 percent for the determination of the constant of atomic distance has been attained $\left(a = \frac{\lambda\sqrt{h^2 + k^2 + l^2}}{2 \sin \phi}\right)$. A single crystal was submitted to a heat-treatment at different temperatures and after every treatment of half an hour an X-ray photograph was successively taken and "a" was determined. The computed values are clearly arranged in tabular form and the photographs reproduced. These reveal only a slight distortion in the geometrical configurations of the space lattice due to the heat-treatment. The obliteration of the strongest reflections at 200° C. and their clear reappearance indicate some changes which cannot be explained as yet. They only allow the conclusion that the whole of the heat treatment is accompanied by small bends of the crystal surfaces of approximately 1° which effect only represents a fraction of the effect of cold working. By annealing up to 200° C. no change takes place. ($^1/_2$ hour anneal.) Above 200° C. the reflections appear obliterated, the precipitations occur inhomogeneously. At 300° C. according to "a," the precipitation was already almost completed. Above 350 and 400° C. the reflections are again distinct; the precipitation is actually completed. The decrease of "a" above 300° C. proves the redissolving of some Cu. A second series of tests was performed with annealing times of 24 hours. In this case the end of precipitation was obtained at 200° C. In order to disclose connections between these precipitations and the mechanical properties, tensile tests with single crystals were carried out, the results of which are presented in tables and diagrams. Since the properties of crystals depend on their orientation, shearing strengths are derived from the values of tensile strength. The curves are similar to those of pure Al crystals, only the strength is greater. The yield point is not quite distinct on account of abrupt increase in strength. The yield point of the quenched specimens is lower than that of the age-hardened ones up to 200° C. ($^1/_2$ hour). The curves and some peculiar results are discussed. The partly unexpected slope of the curves indicate heavy disturbances of crystallographic slippage in the region of inhomogeneous precipitations. The age-hardened crystals behaved in their elastic properties and torsion-like single crystals. Summarizing the results: Precipitations occur after treatments, when age-hardening has already passed its peak. Age-hardening results in an increase of strength without decrease of elongation and reduction of area. Accordance between fine crystalline samples and single crystals were noticed. The immediate effect of precipitations in finely dispersed form is the increase of the strength in the first stage of elongation and an obliteration of the yield limit, that is to say, a bent curve. Only greater amounts of precipitations produce this effect. The effect of treating must be clearly differentiated from the mechanical effect of finely dispersed crystalline or amorphous precipitations. The ageing process takes place at unaltered space lattice of the solid solution without being detectable by optical or X-ray methods. While tempering at 100° C. even for a long time had no effect, 24 hours at 150° C. were sufficient to precipitate about 20 percent. The ageing effect seems to be produced in agreement with Fraenkel by procedures within the crystal lattice by the precipitation of $CuAl_2$ molecules. From this viewpoint it will be of interest to know whether the precipitations are so fine as to be considered as single molecules or whether there are greater complexes of atoms. EF

Inner Stresses in X-Ray Photographs. (Innere Spanunngen im Röntgenbild.) V. Goeler and G. Sachs. *Mitteilungen der deutschen Materialprüfungsanstalten*, Sonderheft V, 1929, pages 151–152.

Reproduction of tests made with interference lines of Kα radiation of Cu on a tungsten wire at different temperatures up to 1200° C. Above 900° C. the double lines which are indistinct at low temperatures can be distinctly seen. Ha

Crystal Structures of Some Binary Compounds of the Platinum Metals. (Ueber Kristallstrukturen einiger binärer Verbindungen der Platinmetalle II.) L. Thomassen. *Zeitschrift für physikalische Chemie*, July, 1929, pages 277–287.

The author describes his method to produce the binary platinum compounds Pd As_2, Pt P_2, Rh S_2 and Pt Sb. The lattice constants are determined test results given in detail. Ha

X-Ray Investigation of the Structure of Tempered Carbon Steel. (Roentgenographische Untersuchung der Struktur des angelassenen Kohenstoff stahls.) G. Kurdjumow. *Zeitschrift für physik*, July 13, 1929, pages 187–198.

The changes of the properties of hardened steel during drawing in the temperature range of 100 to 150° is connected with the disintegration of the tetragonal structure which, at this point tends to change into the cubic structure. The velocity of this process is small at 100 and increases fast with the temperature. The Roentgenograms of the product of the first conversion are distinguished from those of iron only by the indistinctness of the lines; the position of the latter is identical. The indistinctness decreases gradually with increasing temperature. At 250° C. Austenite is quickly disintegrated. The third conversion forms a mixture of small crystals of iron and cementite; the latter grow rather slowly at temperatures of from 300 to 400° C. Ha

The Microstructure of Rapidly Cooled Steel. J. M. Robertson. *Preprint No. 12, British Iron and Steel Institute*, Spring meeting, 1929.

This work was done for the Wire Ropes Committee of the Safety in Mines Research Board, and has to do with "patented" wire. The work is somewhat analogous to that of Lewis reported at the same meeting. Wire of 0.11″ diam. of 0.75% C steel was quenched in molten lead, tin or Wood's metal. In this work only the structure was studied, no data on hardness or physical properties being given. The time the specimen was left in the molten bath is not stated so that it is impossible to tell whether the molten bath operated as a drawing bath as well as a quenching bath. The work was aimed toward clarifying the theory of the behavior of steel at the Ar′ and Ar″ points. Under the condition under which Lewis worked he found 230° C. to be the temperature of the molten bath which would overrun Ar″ and retain austenite which would then, on cooling to lower temperatures, transform to martensite. Robertson, however, found no change in microstructure by lowering the molten bath below 320° C. He interprets his results as indicating that Honda's assumption that austenite passes through sorbite and troostite on its way to martensite, is erroneous. Instead, he concludes that at the Ar′ the troostitic structures are obtained directly from austenite, the change being initiated by the formation of cementite from supercooled austenite. On super-cooling through Ar′, so that the temperature of the Ar″ change is reached before austenite alters, the allotropic change from gamma to alpha iron takes place and it is this which initiates the change at Ar″. The effect of increase in rate of cooling is not the same upon the formation of cementite and upon the allotropic change. The former is slightly lowered, interrupted and finally suppressed, while the latter is progressively lowered. The structures obtained by cooling at different rates cannot be obtained by tempering other structures. The ultimate constitution may be the same, but the crystallographic form and general properties are different. Robertson's conclusions as to the theory involved appear to fit in with those of Lewis and with the idea of Hallimond. It is a pity that the experimental details are so sketchily given. Only one steel was used, and this is described only as "0.75% C," no other sizes than the 0.11″ diam. wire were used. Over 40 micrographs are shown but in the absence of information as to the time the wire was left in the molten bath, one is at a loss to judge whether the structures shown are the result of quenching or of quenching and tempering. HWG

X-Ray Examination in the Shop. (Roentgenuntersuchungen im Werkstättenbetrieb.) O. KANTNER AND A. HERR. *Metallwirtschaft*, June 14, 1929, pages 575–578; June 21, 1929, pages 602–606.

The practical application of X-rays for the purpose of determining the presence of defects, inhomogenieties and the gross structures of materials is described. The value of the radiographic method of inspection is fully outlined by several practical examples to a welded, cast iron valve-casing, cover, and a piston rod, and locomotive parts. Several photographs including interesting data as for instance, thickness and kind of material, exposure time, kilovolts, milli-amperes, distance, etc., clearly illustrated the possibility of the investigations leading to the disclosure of internal defects as inclosures, unsoundness, gas cavities, surface cracks, shrinkage cavities. Furthermore improper treatment of material due to the forming operations (welding, riveting, hardening, rolling, extruding, etc.) and failures are successfully identified by the described method. The practical carrying out of the method of radiological diagnosis is thoroughly explained. A more recent advance, the application of stereoscopic radiography, is discussed ascertaining the depth and angular disposition of inhomogenieties. The problems of the shop solved up to the present by X-ray radiography are summarized and the economical limits mentioned depending on time, wave-length of radiation, thickness and matter of the examined material and last but not least its value. Therefore, in conclusion two practical examples for the calculation and economy of X-ray testing destined for every day use and not scientific work, are presented. EF

An X-Ray Study of Copper which Showed Directional Properties on Cupping. A. PHILLIPS AND G. EDMUNDS. Preprint No. 48, for publication in *Proceedings of the American Society for Testing Materials*, **29** (1929), 10 pages.

The formation of four "ears" 90° apart on cupped copper or steel is obviously connected with directional properties of the metal. The crystal fragments produced by cold rolling are oriented rather at random up to some critical degree of reduction, but beyond that, slip, which occurs on the lattice planes of easy glide, tends to place the crystals in orderly arrangement. Since each crystal has different properties, different ability for further slip, in different directions, the properties of the polycrystalline mass will be different in different directions when the crystals are lined up in ranks all pointing the same way. If the crystals lie at random the directional properties of the individual crystals cancel out in the mass. X-ray pinhole diffraction patterns offer a means of tracing the degree of preferred orientation of the crystals. Too heavy reduction in cold rolling of copper is shown by this means to give strong directional properties after annealing. A reduction of 65% in cold rolling of copper does not cause preferred orientation that will product "ears," with annealing temperatures after cold rolling of 500–600° C. Higher reductions, especially if followed by an anneal at a higher temperature, will cause the "ears." The work shows the ability of the X-ray method to explain phenomena of this type. Other investigators have stated that the direction of rolling coincides with the $\bar{1}21$ crystallographic direction of the copper lattice. Phillips and Edmunds find it to be the $\bar{3}53$ direction. HWG

The Liquidus and Solidus Ranges of Some Commercial Steels. (Sec. II of the Third Report on the Heterogeneity of Steel Ingots.) J. H. ANDREW AND D. BINNIE. *Advance copy, British Iron and Steel Institute*, Spring meeting, 1929.

Many experimental difficulties had to be overcome in this work. Melting was done in a Mo wound furnace in an atmosphere of carefully dried $N_2 + H_2$ from cracked NH_3. This decarburized the melt, until a SiC crucible was used. Using the SiC crucible, lined with alundum cement, and packing alundum about the specimen, covering it with alundum and finally with SiC, it is claimed that the specimens could be melted and remelted without change in carbon content. The specimen was 4 cm. × 1 cm. diam. with a hole in it for insertion of the W-Mo thermocouple. The couple was calibrated to 1200° C. against a Pt-PtRh couple and used up to 1550° C., calibration above 1200° C. being by extrapolation from a parabolic equation. The actual temperature e. m. f. relations of three couples used all differed. The extrapolated curve was checked by the melting point of Armco iron, assumed as 1537° C. As a base line, Armco iron and crucible steels of 0.22, 0.48, 0.41 and 0.90% C with 0.08 to 0.18% Mn were used. The equilibrium diagram based on these is considered an approximation only. The solidus is drawn as a straight line from 1537° C. at zero carbon to 1480° C. at 0.90% carbon. The liquidus is drawn as a straight line from the peritectic horizontal at 0.18% C and 1494° C. to 1330° C. at 0.90% carbon. The peritectic horizontal meets the liquidus at 0.71% carbon. The liquidus appears to be plotted from cooling curves, the solidus from heating curves. The first heating curve is said to show irregularities at about 1400° C., which were absent from later heating curves if the specimen was not cooled below 900° C. It is said that in every case the solidus point in the second curve coincided "exactly" with the first. Only one heating curve (evidently the second) is plotted for any steel and some of the breaks in the curve at the solidus are so gradual that the selection of the temperature is obviously a matter of judgment. It is impossible to evaluate from the data given the magnitude of the experimental error that is inherent in measurements of this kind. Plain carbon steels with Mn up to 0.55% and Si to 0.35% fitted the diagram fairly well, and these amounts of Mn and Si are said to be "quite without effect on either the freezing or melting points." Some of the solidus points come about 20° C. below the line for the crucible steels. Several Ni and Ni Cr steels were tested. The liquidus lay below and the solidus slightly below the equilibrium diagram for the carbon steels. Since the freezing range is thus reduced by Ni, that is given as an explanation for smaller segregation of Ni steels. The depression of the freezing point (liquidus) is calculated as 4½ to 5° C. per 1 percent of Ni or Cr. That is, Cr is assumed to lower the freezing point exactly as much as Ni. No simple Cr steels were tested, however. That the solidus of the Ni Cr steels is close to that of the carbon steels is cited as evidence that these elements do not separate as carbides, but instead exist in solid solution in the iron–carbon system. That two NiCrMo steels showed a marked lowering of the solidus as compared with NiCr steels of the same C, Ni and Cr content, is taken as indicating that Mo steels segregate and that Mo separates as a molybdenum-iron carbide. The Mo content of the two steels was 0.16 and 0.43%. A 6.25% W steel was tested and its solidus is above the carbon steel solidus line but no comment is made on this fact. If the comment on Mo is justified one would expect that W would act like Mo. A 1.18% Mn steel also shows a solidus slightly above the carbon steel curve. No comment is made, but on the line of argument of Andrew and Binnie this would mean that manganese did not form a carbide. The mechanism of the peritectic transformation is discussed in detail. While some rather categorical conclusions are drawn on some points from tests on none too wide a variety of steels, and it is difficult to believe that under the experimental difficulties involved the precision of the work is what the authors evidently believe it to be, these points will probably be cleared up in future work, since it is expected that most of the industrial steels will finally be dealt with. HWG

The Solubility of Iron and Manganese Sulphides in Steel. (Sec. III of the Third Report on the Heterogeneity of Steel Ingots.) J. H. ANDREW AND D. BINNIE. *Preprint No. 1, British Iron and Steel Institute*, Spring meeting, 1929.

Thermal analyses curves of Armco iron plus 0.35 and 0.50% S and of Armco plus 1.40% Mn, 0.31% S and 1.30% Mn, 0.26% S, are interpreted as showing that some sulphur or iron sulphide is held in solution on rapidly chilling the melt, and that even in slowly cooled specimens a small amount may be retained in solution. On the other hand, if manganese sulphide is at all soluble in solid iron, it is only very slightly so. HWG

The Transformation of Austenite into Martensite in an 0.8% C Steel. D. LEWIS. *Preprint No. 7, British Iron and Steel Institute*, Spring meeting, 1929.

Steel of 0.79% C, 0.45% Mn, 0.22% Si, 0.01% P, 0.023% S, 0.09% Cr, 0.01% Ni, 0.06% Cu, such as was used in the Mt. Hope bridge and which approaches rail steel composition, was found to be austenitic when quenched from 815° C. into a salt bath at 230° C. It would remain austenitic for at least 5 minutes at 230° C. and forming operations could be carried out upon it. Air cooling, or any more rapid cooling from 230° full hardening to martensite in wire of 0.192″ diam. By drawing without cooling the quantity of martensite could be controlled. On quenching into salt or other medium at a temperature below 230° C. martensite was formed directly and rapidly. This temperature appears to be a dividing line for this steel between martensite formation from the metastable and from the labile state (see Hallimond, *Jour. Iron & Steel Inst.*, **1922** (I), page 359). No larger sizes than the 0.192″ diam. wire were tested. Were data on larger sizes available interesting possibilities on the heat-treatment of rails might be opened up. HWG

Metallography and Macrography

Constitutional Diagrams for Cast Iron and Quenched Steels. A. L. NORBURY. *Preprint No. 9, British Iron and Steel Institute,* Spring meeting, 1929. 26 pp.

Norbury finds that various cast irons may solidify with widely different microstructures, combined carbon content, tendency to chill and mechanical properties, even though two lots may have identical chemical composition and be cast under identical conditions, if only the melting conditions are different. This is ascribed to the effect of the presence or absence of undissolved graphite flakes which may or may not exist, as Piwowarsky and others have argued previously, according to the superheating to which the melt is subjected.

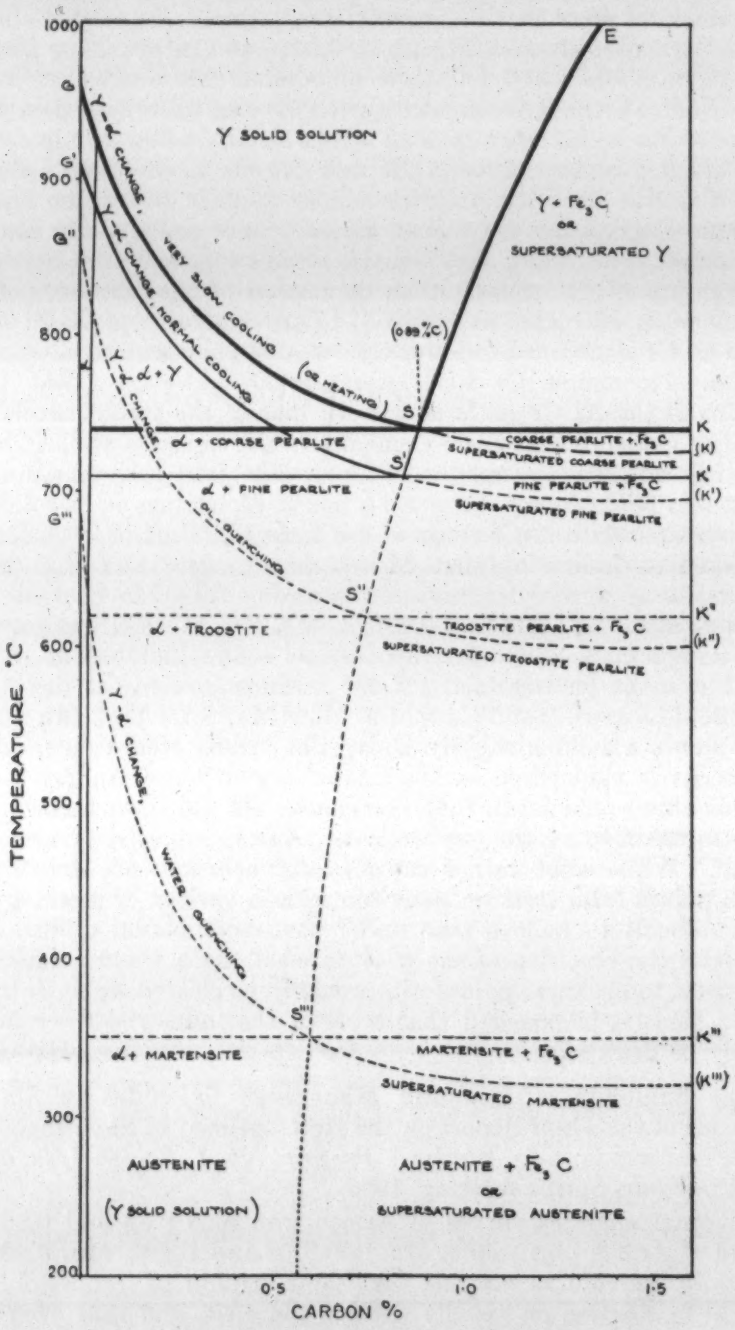


Fig. 1—Constitutional Diagram for Quenched Steels

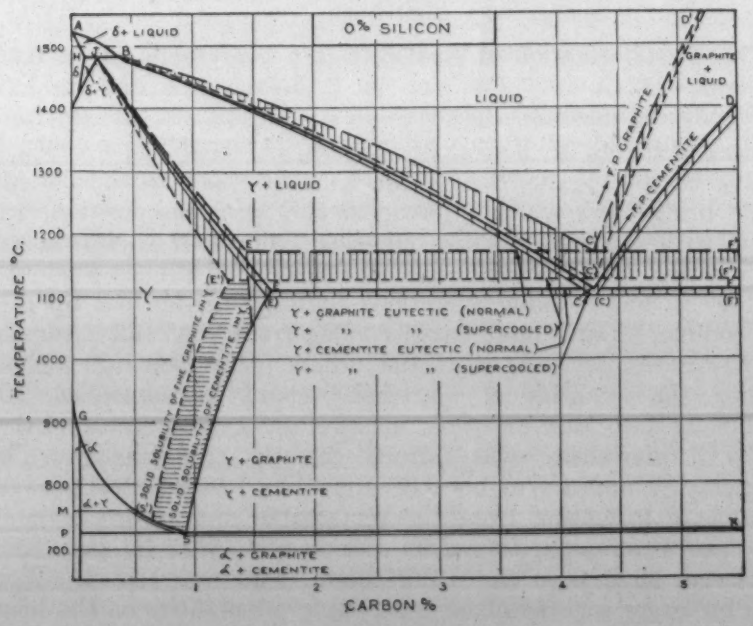


Fig. 2—Constitutional Diagram for Cast Irons Containing No Silicon

Superheated irons, free from graphite nuclei, naturally are more subject to supercooling on freezing and throw out much of their graphite in a very finely divided form and have greater tendency to chill, while those less highly heated, containing the graphite nuclei, deposit their graphite in coarse form and have less tendency to chill.

This behavior is compared with that of Al-Si alloys in which the alloys "modified" by sodium show a finer structure and a higher percentage of silicon in the eutectic than is the case of the unmodified alloys. Norbury assumes that this behavior is due to the fluxing out, by the sodium, of oxide particles which he thinks would act as nuclei and thus prevent supercooling.

On the basis of his experiments, he shows constitutional diagrams for iron with zero to 5.5% C without silicon, with 2% silicon and 4% silicon in which the normal graphite equilibrium, the normal cementite equilibrium, and the constitution for each system when maximum supercooling is permitted by absence of nuclei. He differs from Yensen[1] in showing allotropic transformations in pure iron, but does indicate freedom from allotropic transformations in iron with 2 and 4% silicon. Since Yensen's hypothesis

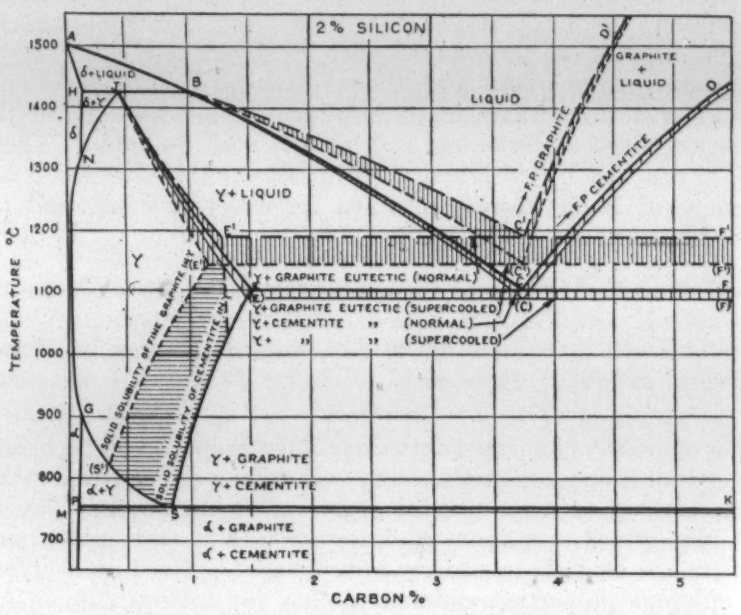


Fig. 3.—Constitutional Diagram for Cast Irons Containing 2 Per Cent of Silicon

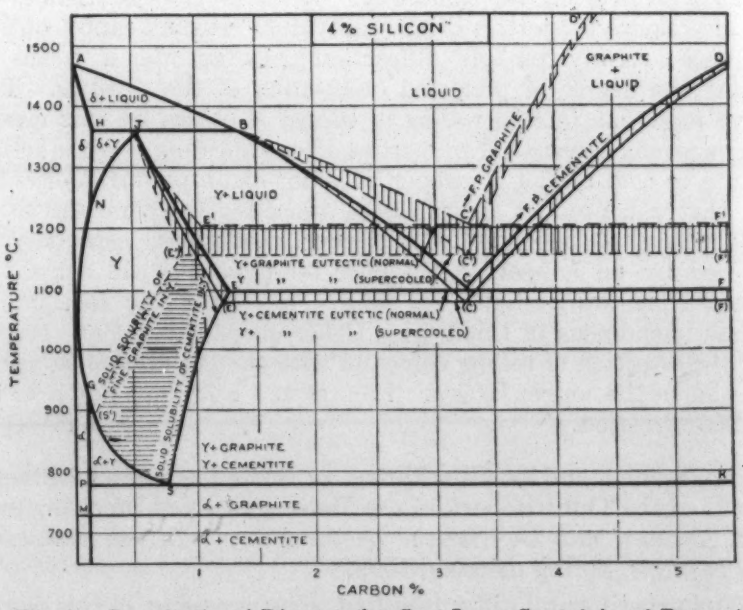


Fig. 4.—Constitutional Diagram for Cast Irons Containing 4 Percent of Silicon

is largely based on experience with silicon steels one wonders whether Yensen has extrapolated too far or whether Norbury has not been willing to run counter to tradition in the case of pure iron.

Norbury applies the supersaturation theory, much as Hallimond[2] did, to quenched steel. He produces the cementite solubility line SE of the equilibrium diagram for iron-carbon below the eutectic point and shows "supersaturation lines" for the depression of the gamma-alpha change at various rates of cooling in quenching. Depending on the temperature at which the line SE produced cuts the depressed gamma-alpha line, pearlite, primary troostite, martensite or austenite, is produced on quenching.—H. W. GILLETT.

[1] T. D. Yensen, "Pure Iron and Allotropic Trnasformations," *Am. Inst. Min. & Met. Eng., Tech. Pub.* **185** (1929). (See METALS & ALLOYS, Nov. 1929, page 237.)

[2] A. F. Hallimond, "On Delayed Crystallization in the Carbon Steels; the Formation of Pearlite, Troostite and Martensite," *Jour. Iron and Steel Inst.* (I), **105**, 359 (1922).

Preparing Thin Specimens for Microscopic Examination. R. A. RAGATZ. *Mining and Metallurgy*, August, 1929, pages 372–379.

This paper is a résumé of the tests carried out and gives recommendations as to the best methods for the handling of various types of specimens as wires, zinc battery cans, hosiery knitting needles, metal lath, etc. Twenty remarkable microphotographs of different metals and alloys of small external dimensions offering difficulties in grinding and mounting are given. Benefits of plating are mentioned. A systematic series of tests was performed to determine what mounting materials were satisfactory for the more widely used metals and alloys. The properties of the various mounting materials as Lipowitz alloy, iron cement, litharge and glycerin, plastic magnesia cement, sulphur, etc., are fully discussed and results of the experiments are clearly arranged in a tabular form. EF

PHYSICAL, MECHANICAL AND MAGNETIC TESTING

The Significance of Damping Ability in Regard to Quality of Materials. (Die Bedeutung der Dämpfungsfähigkeit für die Gütebestimmung von Werkstoffen.) O. FOEPPL. *Metallwirtschaft*, May 3, 1929, pages 419–422.

Damping means the amount of energy transferred into heat per vibration in the unit of volume. The principles of damping are graphically and mathematically outlined. Previous publications are critically discussed, whereby the relationship of surface sensitiveness and damping ability play the most important role. Some tests and their results with cast iron, normal steel 48 and duraluminum are given. Although theory is still in its infancy, damping capability can be used in determination of surface sensitiveness. Damping ability at any stress, f. i., at vibration strength, the ultimate damping is a property which can be determined independently of testing conditions and methods, the ratio between plastic deformation and total deformation. The importance of this portion of plastic deformation in judging of materials under continuous working conditions is evident since it can be endured without harmful effects upon the material. The ultimate damping of dynamic stress corresponds to the ultimate elongation in static stress, the first representing the portion of plastic deformation which can be withstood as often as desired, while the latter signifies the plastic deformation in case of single stress causing fracture. EF

Metal Conductivity and Its Change in the Magnetic Field. (Die metallische Leitfähigkeit und ihre Veränderung im magnetischen Feld.) P. Kapitza. *Metallwirtschaft*, May 10, 1929, pages 443–446.

Specific conductivity of metals is not only influenced by temperature, physical state and the presence of impurities, pressure or strain, but also by the influence of a magnetic field. The present paper deals with the influence of strong magnetic fields of 300,000 Gausses upon resistance which at first increases as the square of the magnetic field and then becomes a straight line function as investigations with 35 metals revealed. Two characteristic curves of copper wires—one annealed and the other hard drawn—are given in a diagram wherein the relative increase $\Delta R/R$ is plotted against the magnetic field. The annealed wire exhibits a larger change in resistance. A new theory is developed dividing the resistance into an ideal and an additive one. Another diagram in which specific resistance is plotted against the magnetic field shows that the additional resistance of hard wires is greater than that of soft ones. Experiments furthermore proved that small amounts of impurities exclusively influence the additive resistance. The ideal resistance is only a function of temperature. Parallels are drawn to the constant resistance at 20° C. abs. (Kammerlingh Onnes) which is identical with the additive resistance. Supra-conductivity means the vanishing of this additive resistance. Some further important conclusions are drawn. The latest electron theory of conductivity by Sommerfeld and the works of Block and Peierls are discussed, but there is no theory explaining the phenomen of the influence by the magnetic field. A new interpretation is attempted by the author. Further experiments to support the assumptions are under way. EF

Recording Pressure Gage with Permanent Adjustment. (Manometre enregistreur a controle permanent.) R. GUILLERY. *Revue de Metallurgie*, June, 1929, pages 329–333.

Description of a recording pressure gage in which the piston is replaced with a ball. JDG

Hardness Tests Research Committee. Review of Hardness Testing. *Iron and Coal Trades Review*, July 19, 1929, page 78.

An abstract of a synopsis by G. A. Hankins on the present state of knowledge of the hardness and abrasion testing of metals with special reference to the work done during the period 1917–27. Indentation hardness tests, abrasion or wear tests, and scratch-hardness tests are considered. The main suggestions in connection with indentation tests and scratch tests are: (1) the need of a clearer and fuller understanding of the meaning of the tests already in use; (2) an investigation of the limits of the distorted zone of material under a Brinell impression for representative materials would enable more exact test dimensions to be specified, and lessen the risk of doubtful results; (3) the provision of standard specimens of a particular Brinell number would afford a cheap and easy method of checking the accuracy of machines in every-day use; (4) experiments should be made to afford standardization of a representative diamond indentation test; (5) the Herbert pendulum "induced hardness" test appears to be of distinct value and worthy of study relative to measurement of the work-hardening properties of steels; and (6) recent applications of the diamond scratch test are particular forms of the indentation test, and it is proposed to make an application of the diamond scratch purposely arranged to produce sliding abrasion and not flow under pressure, which might permit translation of results into resistance under particular conditions. WHB

The Cloudburst Hardness Testing Machine. (Der Cloudburst Härteprüfer.) O. SCHLIPPE. *Metallwirtschaft*, July 19, 1929, pages 701–703.

A new hardness testing machine is described and illustrated, which permits hardness tests on an area of 12 square inches by a hail of 10,000–20,000 steel balls of 3-mm. diameter. The new apparatus discloses irregular, non-uniform hardness on surfaces and the degree of hardness. Besides these hardness tests, the inventor suggests cold hardening of surfaces by this method. EF

ELECTRO-CHEMISTRY

Electroplating

Many Important Topics Discussed at Electroplaters' Annual Convention. *Metal Cleaning and Finishing*, July, 1929, pages 263–268, 295–296.

Report of the seventeenth annual convention of the American Electroplaters' Society held at Detroit, Mich., July 8–11, with abstracts of the papers presented. MS

Electroplating on Aluminum and Its Alloys. (Les depots electrolytiques sur l'aluminium et ses alliages.) HAROLD K. WORK. Translated by A. POULAIN. *Revue de Metallurgie*, July, 1929, pages 378–390.

A translation on the paper "Electroplating on Aluminum and Its Alloys," read by Harold K. Work before American Electrochemical Society and printed with discussion in the *Transactions of American Electrochemical Society* **53**, 361–387 (1928). JDG

INDUSTRIAL USES AND APPLICATIONS

Cast Iron as Working Material and Structural Material. (Das Gusseisen als Werkstoff und Baustoff.) *Mitteilungen der deutschen Materialprüfungsanstalten*, Sonderheft V, 1929, pages 1–11.

In this paper read before a special convention the properties of gray cast iron are discussed in their relation to graphitic deposits, addition of Si, Mn, P and S, the influence of the cooling velocity on the tensile properties and the refinement by alloying. The influence of high temperature is further discussed because of its importance for the construction of steam turbines. The metallographic structure in its relation to corrosion is treated and it is shown that the precipitation of graphite is of utmost importance. The author contends that the control of the properties of gray cast iron is bound up with the control of the precipitation of graphite during and after the solidification. HA

British Methods of Steel Aircraft Construction. W. H. SAYERS. *Aviation*, August 17, 1929, pages 370–374.

The achievements of some firms which have contributed to the development of steel aircraft construction are outlined and a large number of applied profiles are illustrated. EF

Lautal as a Material for Airplane Construction. P. BRENNER. (Translation by D. M. MINER of portions of an article in the 1928 yearbook of the Deutsche Versuchsanstalt für Luftfahrt, pages 127–128 and 156–163.) Technical Memo No. 524, Natl. Advisory Committee for Aeronautics, Washington, D. C. (Mimeographed.)

Lautal is a heat-treatable light aluminum alloy used in Germany. It contains about 4% Cu and 2% Si (thus being somewhat analogous to the American Al-Cu-Si alloy 25S). It requires artificial aging at elevated temperature to develop maximum strength. The article deals chiefly with structural details in the application of the alloy to aircraft construction, containing little of a metallurgical nature. In the rare cases where a weld can be hammered and then heat-treated lautal welds can be made to show nearly the strength of sheet. It is stated, however, that all joints of vital importance in aircraft should be riveted, not welded, since welded joints are not as reliable. No mention is made of the susceptibility of the alloys that require high temperature aging to intercrystalline embrittlement by corrosion. HWG

Light Metals in Aircooled Radial Engines. (Das Leichtmetall im luftgekühlten Sternmotor.) FRITZ GOSSLAU. *Zeitschrift für Metallkunde*, July, 1929, pages 224–227.

This article compares water and air-cooled airplane motors, and discusses the limitations of the latter type resulting from difficulties in dissipating heat. Conversion into useful energy is only 30 percent according to the heat-balance. "Balance-heat" must be emitted from the hot engine parts at a serviceable temperature. Development in construction of cylinders is demonstrated and difficulties of cooling discussed. The predestination of light metals due to their favorable thermal properties has proved true, especially after experiences and calculations led to the best distribution of heat-load. Extremely big heat amounts at the cylinder head are dissipated through a cap of light metals. The investigations in the wind tunnel of the Siemens Laboratories on the cooling effect and heat emission are described and the cylinders and the sections as well as the results of the tests are presented in photographs, drawings and diagrams, respectively. A plain Al cap emits the heat better than a cast iron one which effect can be tripled by the application of ribs. The improved methods of cooling resulted in an increase of output of 44 percent and in a saving in fuel consumption of 17 percent without any change of the dimensions of the cylinder. On the other hand, the inlet valves could remain in place ten times as long as before until seating became a necessity. The problems of cooling, becoming more and more complicated with increased capacities of cylinders, are setting a limit at the present time at 70 hp. in each air-cooled cylinder. It is doubtful whether there will soon be found better designs than those including a screwed on long cap of light metal. An improvement could result from metallurgical progress by furnishing alloys with better heat conductivities with sufficient large heat stability at the same time. EF

Oxygen Cylinders Made of Light Metals in Use for Portable Respiratory Apparatus. (Sauerstoff Flaschen aus Leichtmetall für freitragbare Atemgeräte.) *Zeitschrift für Metallkunde*, July, 1929, pages 235–237.

Tests of the Staatliches Materialprüfungsamt Berlin-Dahlem with new light metal bottles (Lautal) in order to replace steel cylinders are described. The results and all data of interest are collected in five tables. The ultimate strength of 525 atmospheres (average) is only 10 atmospheres smaller than that of steel (average). Tensile strength determined by hydraulic pressure tests: 33–37 kg./mm.^{2} Corrosion tests exhibited but unimportant attacks. A distinct change in diameter after pressure tests according to the existing police specifications could not be noticed. Results of tensile and bending tests vary considerably. The reduction in weight amounts to 2.1 kg. from the original weight of the steel cylinders of 4.0 kg. The cylinders successfully passed the State's examination and can be used for industrial purposes. EF

British and American Automotive Steels. Part 3. J. W. URQUHART. *Heat Treating and Forging*, Aug., 1929, pages 986–990; *Blast Furnace and Steel Plant*, Aug., 1929, pages 1161–1164, 1171.

Reviews the practice with regard to steels in favor at present. The components of the chassis and the appropriate steels are discussed. Gives composition and heat treatment of carbon steels and the purposes for which they are used. Presents also composition of castings used, which may be termed semi-steels. Discusses their behavior under test and their heat treatment. Pays some attention to the latest high tensile steels. MS

EFFECTS ON ELEMENTS ON METALS AND ALLOYS

Der Einfluss des Phosphors auf die Graphitbildung. O. VON KEIL UND R. MITSCHE. *Stahl und Eisen*, July 18, 1929, pages 1041–1043.

Examining several melts of pig iron with high silicon contents (2.1–2.9%) and phosphorus (2.1–2.9%) the authors state that the increase in graphite, which was also found by other authors in similar alloys is due to the shifting of the eutectic point to a lower concentration of carbon. Therefore, it is concluded that a high content of phosphorus in pig iron does not promote but prevents the segregation of graphite. GN

CHEMICAL ANALYSIS

Determination of Lithium in Scleron Metal and Similar Aluminum Alloys. (Die Bestimmung von Lithium in Scleronmetall und ähnlichen Aluminium Legierungen.) E. SCHUERMANN AND W. BOEHM. *Mitteilungen der deutschen Materialprüfungsanstalten*, Sonderheft V, 1929, pages 158–162.

Description of two methods permitting the determination of even as small amounts as 0.1% Li. One method is based on the precipitation of aluminum-chloride from a hydrochloric solution, the other on the formation of oxides and carbonates and silver chloride. Two examples demonstrate the methods. HA

Sampling of Alloys for Chemical Analyses. (Ein Beitrag zur Bedeutung der Probenahme für die chemische Analyse von Metallegierungen.) DR. ZWICKER. *Chemiker Zeitung*, July 13, 1929, pages 546–547.

Attention is called to ingot segregation and some analysis of red "brass" (80% Cu, 9% Sn, 6% Zn, up to 2% Pb) and white metal (80% Sn, 12% Sb, 6% Cu, 2% Pb) are given, revealing discrepancies in part amounting to 1.7% in samples taken from different parts of the ingot. Taking of samples and proper handling is outlined. EF

A Rapid Method for the Determination of Vanadium in Plain and Alloyed Steels. (Eine Schnellmethode zur Bestimmung von Vanadin in unlegierten und legierten Stählen.) K. RIES. *Chemiker Zeitung*, July 6, 1929, page 527.

Preparation of the solution which is titrated with $N/10$ or $N/20$ $KMnO_4$ solution, is given. Time: 30 min. Modifications when Cr and Wo are present. Some control analyses are included showing the attainable accuracy of the new method. EF

Analysis of Speculum Metal. (Die Analyse von Glanzmetall.) L. SCHWEITZER. *Chemiker Zeitung*, June 12, 1929, pages 457–459.

Determinations of the principal metals Sn, Sb, Cu and Pb and of the impurities As, Fe, Ni, Zn and S are outlined. EF

New Quick Method for Determining Mercury. (Eine neue Schnellmethode zur Bestimmung des Quecksilbers.) G. SAPCU AND G. SUICIU. *Zeitschrift für analytische Chemie*, Sept. 10, 1929, pages 334–340.

This method uses one of the more complex compounds which is weighed directly. It offers the advantage of great accuracy because of the high molecular weight of the compound and it can be applied quite generally. A determination can be made in about one hour. Even very minute quantities, 0.000007 g. Hg in 1 cm.^{3} solution can still be determined. HA

Determination of Silicon. (Beitrag zur Bestimmung des Siliziums.) THEODOR HECZKO. *Zeitschrift für analytische Chemie*, Sept. 10, 1929, pages 327–328.

The author recommends a simple way to accelerate the determination of silicon dioxide exactly by putting a piece of filter paper in the crucible which absorbs the moisture and increases the evaporation surface. HA

New Quick Method for Determining Cadmium. (Eine neue Schnellmethode zur Bestimmung des Kadmiums.) G. SPACU AND G. SUCIO. *Zeitschrift für analytische Chemie*, Sept. 10, 1929, pages 340–343.

A complex compound of cadmium soluble in water is used and the precipitate weighed. As in the same method for mercury the same accuracy and saving time is obtained. HA

Quick Determination of Various Elements. (Schnellbestimmung verschiedenar Elemente nach ihrem Ausfallen nach den Vorschriften klassischer Methoden.) J. DICK. *Zeitschrift für analytische Chemie*, Sept. 10, 1929, pages 352–363.

The method uses compounds which are insoluble in alcohol and ether and unchangeable in vacuum. It is applicable to the determination of nickel, mercury, silver, lead, barium, calcium, bromine, iodine, sulphuric acid and oxalic acid. The method, which is described in detail, does not take more than one-half hour. HA

HEAT TREATMENT

Case Hardening Nitrogen Hardening

The Differential Method for Measuring the Thickness of Hard Cases without Sectioning Them. E. G. HERBERT AND P. WHITAKER. *Advance copy, British Iron and Steel Institute,* Spring meeting 1929, 10 pages.

On the assumption that the Herbert pendulum time-hardness value obtained with a 1 mm. steel ball in the 4 kg. tester measures only the hardness of the case of case-hardened steel, unaffected by the depth of case or the hardness of the core, while the Brinell test gives the resultant of the hardness of the case, its thickness and the hardness of the core, Herbert and Whitaker suggest a "differential" method for determination of case thickness. It is assumed that the Herbert time-hardness value multiplied by 10 for a 1 mm. steel ball or by 13.5 for a 1 mm. diamond ball gives the equivalent Brinell hardness number of the case. If from this equivalent Brinell number be subtracted the observed Brinell number, the difference bears a straight line relationship to the depth of case. Up to a case depth of 0.04″ the 5 mm. Brinell ball with 750 kg. load will serve, for greater depths, the 10 mm. ball, 3000 kg. load should be used. The following table is given, for case thickness on a steel whose core has a Brinell hardness of 288 after quenching:

Case Thickness Inch.	Case Thickness Millimeters	Differential 10 mm. Brinell ball 3000 kg. load	(10T-B or 13.5 D-B)[a] 5 mm. Brinell ball 750 kg. load.
0.004	0.1	450	390
0.008	0.2	430	330
0.012	0.3	407	288
0.016	0.4	386	245
0.020	0.5	364	200
0.024	0.6	341	170
0.028	0.7	321	135
0.032	0.8	300	100
0.035	0.9	276	65
0.039	1.0	256	33
0.043	1.1	237	10
0.047	1.2	218	0
0.051	1.3	195	
0.055	1.4	174	
0.059	1.5	151	
0.063	1.6	133	
0.067	1.7	115	
0.071	1.8	96	
0.075	1.9	78	
0.079	2.0	59	
0.083	2.1	42	
0.086	2.2	26	
0.090	2.3	12	
0.094	2.4	0	

T = Herbert pendulum time hardness number 4 kg. pendulum 1 mm. steel ball.
D = ditto with 1 mm. diamond ball.
B = Brinell number.

The table is not applicable to steels with other core hardnesses than 228. An equation is given by which it is claimed that tables for other core hardnesses may be constructed. If

C = Pendulum time hardness of case, converted to Brinell values,
c = Brinell hardness of the core
M = Minimum case thickness for zero differential
t = thickness of case
d = corresponding differential value for t, then

$t = M\left(1 - \frac{d}{C - c}\right)$. The value M has to be found by experiment, or by making differential tests on cases of known thickness, then solving the equation for M. No description is given of the actual criteria used for microscopic measurement of case thickness in the construction of the table given. The application of the method to determining the thickness of chromium plating and of the nitride case on nitrided steel is under investigation. HWG

WORKING OF METALS AND ALLOYS

Melting and Refining

Recovering Silver from Scrap Material and Preparing the Metal for the Trade. F. A. COLLINS. *Engineering and Mining Journal,* August 3, 1929, pages 164–6.

A brief outline. More than 10,000,000 oz. of fine silver are moved annually from scrap heaps. Waste products treated include: sweeps from the floors of shops where silver is handled, the water used in washing down walls or old woodwork in the factories or shops and the film used in the motion picture industry. WHB

The Physical Chemistry of Rimmed Steel. J. E. CARLIN. *Transactions American Society for Steel Treating,* August, 1929, pages 293–297.

The early method of manufacture of low carbon steels by the basic open hearth process, and the start and development of the rimming process are stated. The physical chemistry of rimmed steel is discussed. ESC

Comparative Study of Oxidation and De-Oxidation Phenomena in the Manufacture of Steel Rails by the Thomas and Open Hearth Processes. (Etude comparative des phenomenes d'oxydation et de desoxydation dans la fabrication des rails par procedes Thomas et Martin.) JOS. WAGNER. *Revue de Metallurgie,* June, 1929, pages 287–296.

Basic OH process was compared with Thomas process in regard to the quality of the rails produced. Three blows of basic (1.84 % P) iron were studied. While Si, C, P are present the degree of oxidation cannot be higher than the one specified by their presence in the system. During the after blow P reduces somewhat the oxides of Fe and Mn and, if the operation is stopped at about 0.04% P a lower oxygen content is found than before the beginning of the after blow (0.106 and 0.095%). The final state of the deoxidation is practically the same in OH and Thomas processes (0.010 and 0.014% O). Non-metallic content is only slightly higher in the latter. Basing on the state of oxidation Thomas process is entirely suited for production of high grade rails. A table of impact values taken on identical sections of OH and Thomas rails of the same composition gives an average of 4.24 kg./m. for open hearth rails and 2.01 for Thomas rails. JDG

Nickel Clad Steel Melting Pots. *Brass World,* July, 1929, page 163.

The International Nickel Company, N. Y., has marketed a melting pot of low-carbon steel or ingot iron coated with nickel by welding. The steel resists the metals within the pot and the nickel on the outside resists the action of air and combustion gases at high temperature. The Niclad pots are only 1/2″ thick, resulting in better heat conductivity and almost negligible drop in temperature. Average life of Niclad pots is claimed to be 7000 hours, against 300 for plain steel and 1000 for special heat resisting alloys. WHB

Casting & Solidifiation

A New Method for the Production of Sound Steel. C. PARSONS AND H. M. DUNCAN *Preprint No. 10, British Iron and Steel Institute,* Spring meeting, 1929.

The "new" method is the oft-suggested one of trying to get the steel to freeze from the bottom up, according to the authors' British patent 278,032. A heavy cast iron chill plate, 6 ft. deep is used as the base of the ingot mold, while the sides are fire brick. The top is roofed over with fire brick and oil or gas flames are introduced at the top to keep the top from freezing till last. The ingot as in the form of a cheese 70″ diam. 45″ high and weighs 46,000 lbs. An ingot so cast, teemed through a 1½″ diam. nozzle, from steel of 0.23% C, 0.65% Mn, 0.24% Si, 0.04% S, 0.045% P, was sampled for segregation. The upper quarter showed distinct C and P segregation at the center, i. e., it was no better than an ordinary ingot in that respect. Macrographs and S prints are interpreted as showing marked improvement. Mechanical tests indicate rather better uniformity than in the average unforged ingot, save where zones of inclusions were met. These are ascribed to pouring with too small a nozzle resulting in scum while the bottom was being flooded. A 3 ton ingot 36″ diam. teemed with a 1 1/8″ nozzle was found to be "entirely free from" transverse defects. The ingot discussed in the paper is apparently the first big ingot so made that has been split and examined in detail, so that it would be unfair to judge the method from the results, which, while not unpromising in some respects, do not indicate that the method can yet be accepted as a cureall for heterogeneity. HWG

The Effect of Latent Heat on the Solidification of Steel Ingots (Sec. V of the Third Report on the Heterogeneity of Steel Ingots). N. M. H. LIGHTFOOT. *Advance copy, British Iron and Steel Institute,* Spring meeting, 1929.

Mathematical discussion of the effect the liberation of the latent heat of fusion may have on the rate of solidification of steel ingots. His mathematics bring him to an entirely different result from that of Feild (*Trans A. S. S. T.* **4,** 264 (1927)) for the same assumed conditions. HWG

Machining

The Present Status of Tungsten Carbide as a Cutting Material. F. C. SPENCER. *Mechanical Engineering*, August, 1929, pages 597–598.

Carboloy and Widia (Krupp-Essen) are mentioned as cutting materials of this type. Experiences obtained by several concerns with cutting of different materials are given, which point out the immense advantages. Machine tools now available limit the application. GN

Pickling

The Influence of Pickling Operations on the Properties of Steel. H. SUTTON. *Advance copy, British Iron and Steel Institute*, Spring meeting, 1929, 24 pages.

The results of many previous workers in this field are confirmed. Pickling in H_2SO_4 has an embrittling tendency on steel, but standing for a few days at room temperature, or immersion in boiling water for half an hour allows the hydrogen to escape and removes the brittleness. Some heat-treateed steels when deformed after certain conditions of heat treatment are likely to develop cracks at the points of deformation during pickling. Some heat-treated steels, tempered at low temperatures, suffer a loss of tensile strength on pickling. Pyridine, quinoline and similar "inhibitors," reduce the degree of embrittlement during pickling. The action is specific, not all organic addition agents are effective. Electrolytic pickling in neutral or alkaline solutions is far less harmful than acid pickling. Anodic pickling is still less injurious than cathodic pickling. HWG

Cold Working

Press Working and Forming of Metals. Part 51. Rate of Strain Hardening in Cold Deformation of Metals. E. V. CRANE. *Metal Stampings*, August, 1929, pages 585–590.

Presents plastic deformation curves to correlate various states of hardness and show the rate of strain hardening of aluminum and steel in cold working. Stress strain curves drawn by an Olsen recording testing machine in the course of punching tests were translated to show actual stress in lbs./in.^{2} upon the continually diminishing cross sectional area of the material in shear. The new curves were than transposed to new positions to indicate a curve which would be the locus of all curves of plastic deformation of the material in whatever state. It indicates also the rising rate of strain hardening as hardness or resistance is increased. Gives an analysis of the effect of direction of loading on nature of deformation. MS

Inner Stresses in Metals. (Innere Spannungen in Metallen.) G. SACHS. *Mitteilungen der deutschen Materialprüfungsanstalten*, Sonderheft V, 1929, pages 144–151.

Of the many factors which are of importance in shaping, testing and in the use of metals, the inner stresses are of a nature which permit a comparatively easy investigation with respect to their effect on the behavior of the metal. The paper discusses in particular two phenomena; tearing (bursting) of pieces of copper formed by cold processes and the peculiar shifting of elasticity and elongation limits after cold-working, called Bauschinger effect. The discussion is illustrated by very complete records of tests. HA

INSPECTION

Artificial Illumination for Tinplate Sorting. R. S. ISAACS. *Iron and Coal Trades Review*, June 7, 1929, page 867.

In general, the defects in tinning or plating that are looked for, fall into two classes: (1) color blemishes, which do not destroy the mirror effect; and (2) surface defects that do. Local indirect lighting of the sorting benches can be obtained by using a dead white diffusing surface of the shape shown in section in Fig. 1. The diffusing as made for sheet iron which has been painted dead white best runs the full length of the sorting bench. The number of lamps required depends on the length of the bench. They should be evenly spaced, and use 25 watts per sq. ft. of bench area. Daylight lamps are best. The difficulty of overcoming the effects of surface defects such as mottling is partly overcome by placing at A B in Fig. 1 a grid of the form shown in Fig. 2. This is painted white on the upper side and black on the lower. The grid gives a dark image of itself in the plate being inspected and at the same time it will only reduce the illumination to a slight extent. If a surface defect should lie over any part of the dark image it will scatter the light and appear white against the dark background. If the plate is pushed forward the grid will not be deflected and color defects can be looked for, while if it is pulled forward the image of the grid will cross the plate and any surface defect will at once show up. WHB

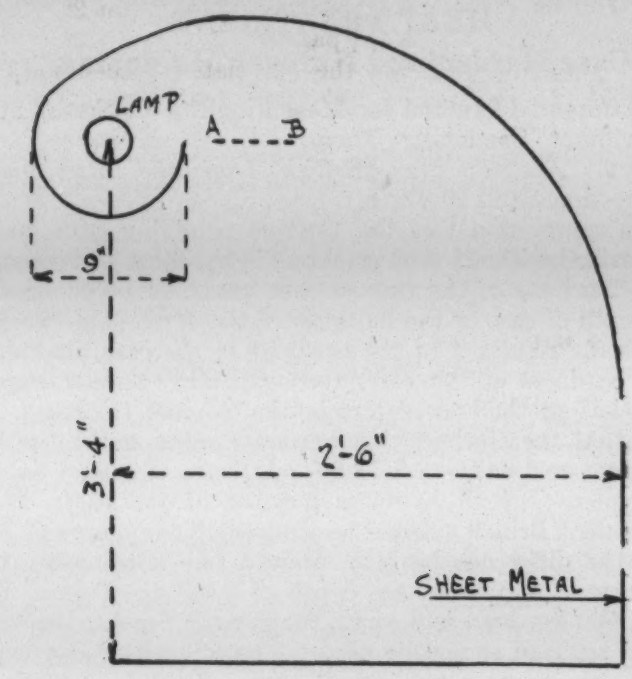


Fig. 1—Lighting Arrangement

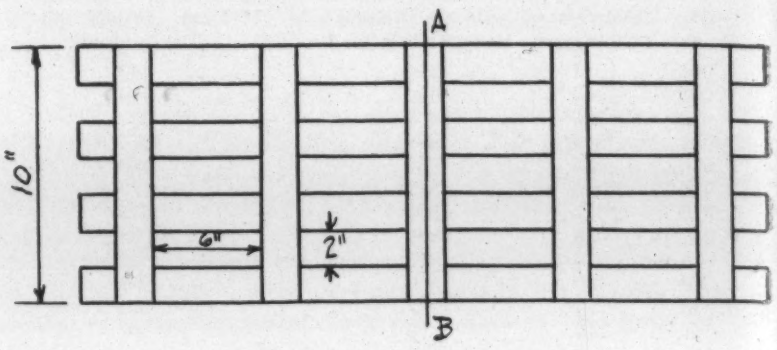


Fig. 2—Painted Grid

FOUNDRY PRACTICE & APPLIANCES

Modern Gray Iron and Steel Foundry for Mass Production. L. W. SPRING. *Journal of the Western Society of Engineers*, Sept., 1929, pages 520–529.

A condensed review of modern practices with an elementary description to make it complete. New requirements due to high temperature and high pressure are responsible for a considerable amount of replacement of cast iron by cast steel. The importance of the selection of the correct sand for molds for the metal being cast is indicated. WHB

High-Test Gray Cast Iron—European Developments. E. E. MARBAKER. Preprint 29–23, *American Foundrymen's Association*, pages 405–416.

Especially the German post-war development in producing high-test cast iron is mentioned. The chief methods refer to decrease of carbon content, control of cooling rate after casting reduction of particle size of graphite and improvement of distribution, (superheating, rapid cooling of high silicon iron, treatment with calcium silicide) alloying with elements such as nickel and chromium, agitation of molten metal, production of eutectic cast iron. All methods are considered briefly. GN

Materials Handling in Gray Iron Foundries. A. WALTON. Preprint 29–11, *American Foundrymen's Association*, pages 235–258.

The paper deals with all operations of material handling in gray iron foundries, as for instance: applications of lifting magnets, portable cranes, tractor trucks, machine charging cupolas, cupola charging, unloading materials, distribution of molten metal, conveyor table mechanism, handling large tonnage of small castings, sand conveying, economical location of cleaning rooms, reduction in molding costs, standardizing of equipment, preparing sands, dust collection and handling. GN

High-Test Cast Iron. R. P. LEMOINE. Preprint 29–12, *American Foundrymen's Association*, pages 259–288.

Annual exchange paper of the Association Technique de Fonderie, France. The paper deals with the present state of the production of high-test cast iron in Europe and chiefly in France. In 2 parts the various scientific results on high-test cast iron examinations and the evolution of the practical side of high-test cast iron production during the last 10 years are given. The influence of composition, as for instance the influence of phosphorus, manganese, sulphur on the one hand, and the influence of cooling speed on the other are discussed. The application of steel, the methods to improve cast iron by a special treatment of molds, the influence of alloying elements, the application of the electric furnace are outlined. Furthermore the improvement of cast iron by a suitable development and handling of the cupola process is mentioned. The fact that some kinds of scrap have a slow carburization resulted in the establishment of a special cupola process in France. GN

Baking Practice of Oil-sand Cores. H. L. CAMPBELL. Preprint 29–13, *American Foundrymen's Association*, pages 289–294.

The chief factors which affect the properties of finished oil-sand cores are time of baking, temperature applied, and atmospheric conditions within the oven. The total baking time may be decreased by using a minimum amount of moisture or volatile oils in the core-sand mixture. The length of time at maximum temperature has a critical effect on the strength of cores. The presence of oxygen is essential to the hardening of oil-sand cores. GN

Some Experiences in Sand Control. E. F. WILSON. Preprint 29–28, *American Foundrymen's Association*, pages 183–198.

The paper gives a series of observations and studies on sand control and synthetic molding sands. The investigations were made to find a sand with a sufficiently high permeability, which is necessary for certain classes of work. GN

Superheating of Cast Iron. (Ueberhitzung von Gusseisen.) P. BARDENHEUER & K. L. ZEYEN. *Mitteilungen Kaiser-Wilhelm Institut für Eisenforschung*, 1929, Vol. 11, No. 13, Report 130, pages 225–235.

To study the influence of superheating on cast iron, samples of about 45 lbs. weight were melted in a high frequency induction furnace and superheated at three different temperatures before casting in test bars in dry sand molds at 1350° C. The superheating temperatures were: group A: 1350–1380° C., group B: 1460–1500° C., group C: 1580–1630° C. Two materials were examined with, (1) low P. and S. content and, (2) with higher P and S content. Both materials were melted with high carbon content (about 3.4%) or low carbon content (3% or less). (1) Melts with low carbon content show a decrease of the physical properties, whereas melts with high carbon content show an essential improvement is due to a fine crystallization of graphite. (2) Similar results are obtained in examining the samples with the higher P and S content. The melts with 3.2% carbon and less show a tendency to crystallize in dendrites. This fact explains the decrease in bending strength. The dendritic crystallization did not influence the tensile strength, which increases in spite of the dendritic crystallization in consequence of the finely distributed graphite. An improvement of superheated cast iron with low carbon content can be obtained by a high silicon content or by adding part of the silicon content as powder in the ladle, or by alloying with chromium. GN

Some Inter-Relationship in Gray-Iron Metallurgy. W. J. BOLTON. *Foundry Trade Journal*, Aug. 11, 1929, pages 85–86.

Paper presented to the International Foundry Congress. A discussion by various authorities of a paper read before the Congress last June. Some of the points discussed are: Future of American research, scientific classification of graphite, seriousness of gas in metal, importance of melting conditions, and the relation of chemical and mechanical properties. VSP

Oxidation Losses in the Cupola. EMIL KNOPPICK. *Foundry Trade Journal*, Aug. 8, 1929, page 96.

Slightly condensed translation from "Die Giesserei." Describes method used in Germany to calculate iron loss by oxidation from slag. VSP

Some Cupola Troubles. Their Cause and Remedy. W. H. BLEEKE. *Foundry Trade Journal*, Aug. 15, 1929, pages 115–116.

Discusses various difficulties which are met while running a cupola melt. Takes up scaffolding, variations in metal composition and leakages. VSP

FURNACES & FUELS

Stand-by Losses of Electric Furnaces Readily Computed. *Electrical World*, Oct. 5, 1929, page 679.

For furnaces of average size having 1 door and at least 9″ of insulation the standby losses can be fairly accurately determined by the formula:

$$\frac{\text{total sq. ft. of inside area} \times \text{furnace temperature in °F.}}{10{,}000} = \text{Kw.-Hr. per hr. of stand-by loss}$$

Losses from opening the door are not included, and formula does not apply to small standard stock sizes. WHB

Furnace for Temperatures up to 2600° C. (Ein Gebläseofen bis 2600° C.) R. JUNG. *Stahl und Eisen*, Aug. 22, 1929, page 1233.

The petroleum fired furnace was constructed to investigate high fusible oxides. The furnace is 6″ high, $3^1/_8$″ diameter, the flames swirl around a vertical pipe of zirconium-dioxide ($^{11}/_{16}$″ diameter). The zirconium-dioxide lining is preheated at about 2000° C. The fuel, mixed with oxygen, is injected finely dispersed through nozzles. To get an equal heat distribution different shaped nozzles were applied. The best results were obtained with 0.09 or 0.094″ diameter nozzles. With these nozzles a constant temperature was obtained in a zone of about 4″. With an oil consumption of 0.6 and 0.71 oz. respectively, 2630° C. were reached in 10 minutes. 50–60 experiments at about 2000° C. can be performed without changing the lining. GN

Material and Heat Balances of Some Melts in the Brackelsberg Furnace. (Stoff- und Wärmebilanzen einiger Schmelzen im Brackelsbergofen). P. BARDENHEUER & K. L. ZEYEN. *Mitteilungen Kaiser-Wilhelm Institut für Eisenforschung*, 1929, Vol. 11, No. 14, Report 131, pages 237–246.

The Brackelsberg furnace is a revolving furnace fired with pulverized coal and especially qualified to melt high-quality cast iron and malleable cast iron. Considered from the metallurgical standpoint the furnace offers essential advantages. Melting is carried out very quickly and the oxidation of iron and alloying elements is small. The solution of gases and oxides is practically eliminated. To investigate the balances three melts of malleable cast iron and gray cast iron respectively were examined. Iron loss by oxidation amounted to 0.65–1.96%, thermal efficiency 28.70–40.74%, exhaust gas losses 45.05–55.36%. The losses by incomplete combustion of fuel can be lowered to less than 5%. The heat efficiency of the furnace is better in comparison with the older melting methods. Suggestions for a further improvement of the process are given. GN

Annual Convention of the "Verein Deutscher Giessereileute," Düsseldorf, September 3-8, 1929

The convention took place during the Foundry Exposition. The president of the society, E. Bock, addressed the numerous members and their guests. Dr. Lehr, the mayor of Düsseldorf, extended a welcome in behalf of the city. The Siegfried Werner Medal was presented to Dr. Osann for his excellent work in the development of foundry technique.

Dr. W. Claus spoke on "Schwindung und Lunkerung" (Contraction and Piping). Contraction is the property of hot metals not to retain their original volume after cooling. Under piping is understood the formation of shrinkage cavities during solidification. Contraction is not a purely physical property of the metal but is also influenced by quenching, recrystallization, structure and the mold material. By suitable treatment it is possible to obtain a dense metal, which is very important with alloys, like Elektron, which must be heat treated.

"Röntgenographische Erkennungsmöglichkeiten von Gusserzeugungsfehlern" (X-ray Determination of Casting Defects) by H. Reininger considered the use of X-rays for the detection of cracks, porosity and non-metallic inclusions. The author also describes the detection of structural failures in castings by means of X-rays.

Dr. A. Thum in his paper "Neuere Anschauungen über die mechanischen Eigenschaften des Gusseisens" (New Observations on the Physical Properties of Cast Iron) stated that the success accomplished in improving the properties of gray cast iron led to a more careful survey of the physical properties. Important research on the fatigue strength of cast irons gave valuable data for the mechanical engineer in the design of cast iron machine parts.—CARL KUETTNER.

Translation

Negotiations are now under way which will assure the appearance of translations of articles appearing in foreign publications. Under this arrangement, the readers of METALS & ALLOYS *will be assured of receiving in English the best articles at almost the same time as they appear abroad instead of three months to one year later.*

Electric Conductivity, Corrosion and Possibilities of Heat Treatment of Cadmium-Zinc Alloys

By G. Grube and A. Burkhard*

(Translated by special arrangement from Zeitschrift für Metallkunde, July, 1929, pages 231–234.)

The Constitutional Diagram

The last complete investigation of the Cadmium–Zinc system was made by Jenkins[1] who found the eutectic point at a temperature of 266° C. with a zinc content of 17.4%. According to his statements the solubility of zinc in cadmium in the solid state at the eutectic temperature amounts to 2.5% and the solubility of Cd in Zn to 2.0%. With falling temperature the solubility decreases and according to metallographic investigations of Jenkins, zinc is able to dissolve 0.25% of Cd and Cd can dissolve 0.8% of Zn at room temperature.

Based on his investigations, Jenkins has constructed a constitutional diagram, assuming that zinc occurs in three polymorphous modifications. This assumption is also encountered elsewhere in literature. Benedicks[2] (for instance) believed he had found by measurements of electric conductivity a transformation at 160 and 330° C. In a later publication[3] however, he obtained in the case of very pure zinc a complete continuous course of the temperature resistance-curve and he proved that even a slight addition of cadmium gives rise to discontinuities on the curve at the temperatures mentioned above. Benedicks, therefore, is of opinion that in the solid state zinc has no transition points at all. We, too, found in case of pure zinc a complete constant slope of the temperature-resistance-curve between 20 and 330° C., while on the other hand Petrenko[4] recently gave transition points at 300 and 175° C., based on thermal investigations. Our own statements are in agreement with the results of Pierce, Anderson and van Dyck[5] on one hand, and with those of Freemann, Brandt and Sillers[6] on the other hand who, basing their opinion on X-ray investigations, state that zinc does not occur in several polymorphous modifications.

We reported, in detail in another paper[7] on the measurement of the electric resistances of Cd-Zn alloys and their evaluation for determining the constitutional diagram. The measurements permitted the exact determination of the concentration of the saturated solid solution in relation to the temperature. The concentrations of the zinc-rich solid solutions are:

at 263°	96.3% Zn	at 212°	97.94% Zn
at 226°	96.92% Zn	at 142°	99.08% Zn

The concentration of the cadmium-rich saturated solid solution amounts to 4.3% Zn at 263°, to 2.97% Zn at 180° and 2.08% Zn at 150° C. Our values for the solubility of the solid metals in each other are consequently larger than those given by Jenkins.

In Fig. 1, the constitutional diagram of the Cd-Zn alloys is reproduced in the upper part, as found, based on conductivity measurements. The freezing curve of the alloys was drawn in the diagram based on the results of Jenkins' thermal investigations. In the lower part of Fig. 1, the conductivity isotherms of the alloys (ordinate: 10^{-4} times as large as the value of the specific conductivity. Abscissa: concentration of the alloy in percent by weight) at 100, 150, 200 and 250° C. are plotted according to our own measurements.

The isotherms exhibit a slope characteristic for a system containing an eutectic and partial solubility in the solid state, i. e., the specific conductivity, starting from the concentration of the pure metals, drops at first on both sides to the saturation concentration of the solid solution. On the side of cadmium—after passing the saturation concentration—the conductivity increases slowly with increasing zinc content in a curve with small curvature until at 96% Zn a distinct break occurs which indicates the passing from the field of two phases with eutectic crystallization into the single phase built up by the zinc-rich solid solution.

These measurements disagree with the results of Glasunow and Matweew[8] who determined the electric conductivity of Cd-Zn alloys at 25° and 100° C. They found a straight-lined course of the conductivity isotherms and thus drew the conclusion of complete insolubility of both metals in the solid state.

Microscopic investigations confirmed the results obtained by resistance measurements revealing that there is no reaction in the solid state besides the occurrence of solid solutions.

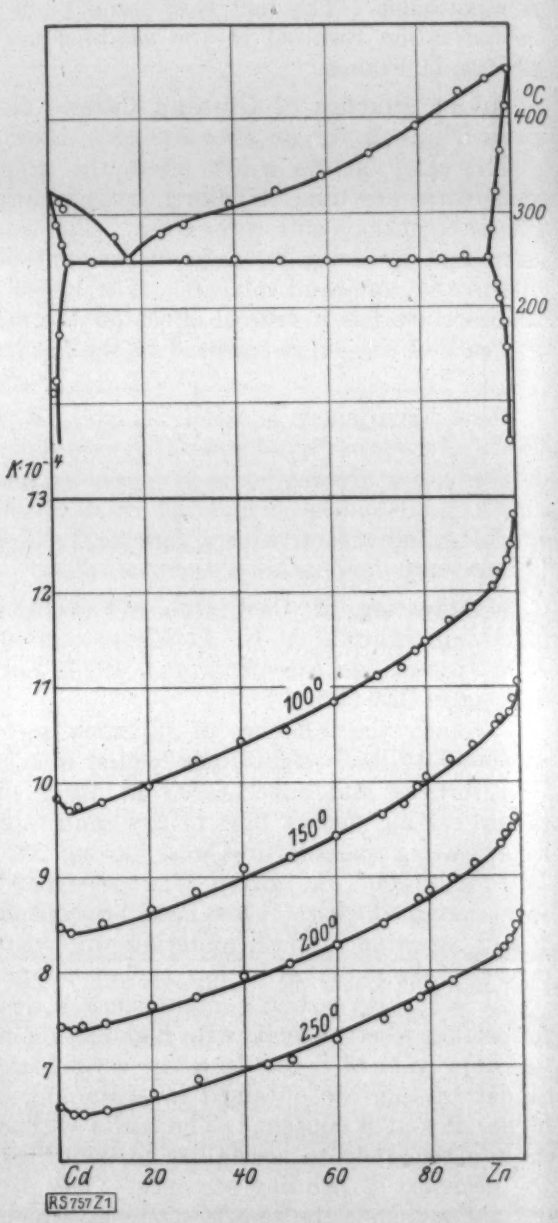


Fig. 1—Constitutional Diagram Based on Conductivity Measurements and Electric Conductivity Isotherms of Cd-Zn Alloys

Corrosion with Sodium Hydroxide

Furthermore the attack of the Cd-Zn alloys by sodium hydroxide has been systematically investigated.[9] In Table 1 experiments, in 1 *n*-sodium hydroxide at 25° C., 2 *n*-sodium hydroxide at 35° and 3 *n*-sodium hydroxide at 20° C. all for 24 hours, are reproduced. Each test was carried out in duplicate and can be found under I and II while under "average" the average value of I and II is given.

Table 1 Corrosion Tests on Cd-Zn Alloys in Sodium Hydroxide. (Duration of Tests 24 Hours)

	Mg. of Zn Dissolved per 1 Cm.² of Alloy Surface								
	1 *n*-NaOH, 25° C.			3 *n*-NaOH, 20° C.			2 *n* NaOH, 35° C.		
% Zn	I	II	Average	I	II	Average	I	II	Average
11.5	0.05	0.07	0.06	0.1	0.1	0.1	0.2	0.2	0.2
17.4	0.2	0.2	0.2	0.3	0.3	0.3	0.7	0.4	0.5
20.7	10.1	6.9	8.5	15.0	10.2	12.6	18.0	14.0	16.0
29.2	8.7	6.5	7.6	10.7	8.9	9.8	12.0	14.6	13.3
40.0	7.9	7.1	7.5	9.8	9.1	9.1	11.6	12.3	12.0
47.5	8.7	7.2	7.9	9.0	7.1	8.0	15.0	8.2	11.6
54.3	7.3	6.4	6.8	7.0	9.4	8.2	10.1	14.5	12.3
60.2	11.0	6.0	8.5	10.0	8.6	9.3	12.3	10.7	11.5
76.6	8.0	..	8.0	12.9	10.1	11.5	10.3	14.6	12.4
82.1	13.0	10.2	11.7	15.3	13.0	14.1	19.0	11.7	15.3
85.5	9.0	6.6	7.8	10.9	8.7	9.8	10.0	10.7	10.4
88.6	8.0	7.0	7.5	8.3	7.0	7.6	10.2	6.2	8.2
100	5.7	5.3	5.5	4.3	4.0	4.1	7.9	6.4	7.1

* Laboratory of Physical Chemistry and Electro Chemistry of the Technische Hochschule Stuttgart.

The graphical representation of the experimental results in Fig. 2 proves that only small amounts of zinc are dissolved between 0 and 17.4% Zn by the hydroxide and that, after passing the eutectic concentration, the attack increases with a bound.

In the second set of tests collected in Table 2, the influence of time and temperature was investigated at the same time holding the concentration constant.

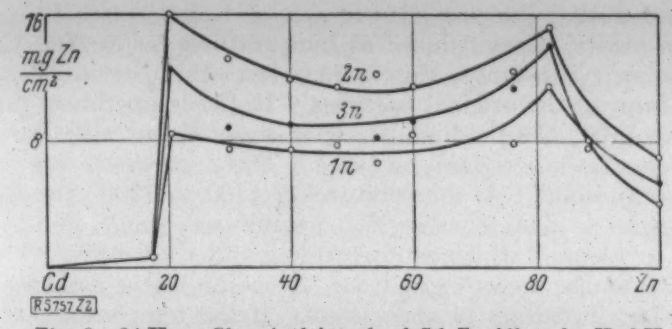


Fig. 2—24 Hour Chemical Attack of Cd-Zn Alloys by NaOH of Different Concentrations

Table 2 Corrosion Tests on Cd-Zn Alloys in Sodium Hydroxide (Corroding Agent 2.9 *n*-NaOH)

mg. of Zn Dissolved per 1 cm.² of Alloy Surface.

	3 Hours at 45° C.			6 Hours at 45° C.			12 Hours at 45° C.			12 Hours at 45° C.		
% Zn	I	II	Average	I	II	Average	I	II	Average	I	II	Average
11.5	0.2	0.2	0.2	0.3	0.3	0.3	0.2	0.5	0.4	...	0.4	0.4
17.6	0.4	0.2	0.3	0.6	0.5	0.5	0.6	0.4	0.5	0.7	0.6	0.6
19.8	1.7	1.1	1.3	1.3	1.0	1.1	2.7	1.7	2.2	6.6	5.3	6.0
29.2	2.5	1.4	2.0	2.4	1.6	2.0	3.7	3.4	3.5	5.0	6.6	5.8
40.0	2.0	1.7	1.8	2.0	2.7	2.4	3.2	3.3	3.3	6.2	6.4	6.3
49.6	2.2	3.0	2.6	3.0	2.6	2.8	5.1	3.2	4.2	5.3	6.5	5.9
54.3	1.4	1.6	1.5	3.9	2.3	3.1	3.2	4.5	3.9	8.0	5.0	6.5
61.0	2.2	2.2	2.2	3.0	3.3	3.2	3.8	3.5	3.6	7.6	6.6	6.8
70.3	...	2.8	2.8	...	3.8	3.8	...	4.8	4.8	...	6.6	6.6
77.0	4.6	3.5	4.0	5.1	4.3	4.7	5.1	5.2	5.2	7.0	5.8	6.1
82.1	...	2.8	2.8	...	4.1	4.1	...	4.8	4.8	...	7.1	7.7
88.7	2.5	2.1	2.3	3.7	3.2	3.4	3.1	3.2	3.1	6.1	6.8	6.4
100	1.5	1.6	1.6	2.7	2.7	2.7	3.2	3.9	3.6	6.4	6.9	6.5

The curves plotted in Fig. 3 from the data of Table 2, as is also the case with Fig. 2, prove that within concentrations of 0–17.4% Zn, i. e., to the composition of the eutectic point, Cd-Zn alloys are practically unattacked by sodium hydroxide. The chemical attack changes suddenly after passing the eutectic concentration, that is to say, that the attack increases with rising zinc-content up to a maximum at about 77% Zn as the curves of Fig. 3 obviously prove. After passing this concentration the attack decreases again somewhat, decreasing toward the side of pure zinc. The break at the eutectic composition is the more pronounced the longer the experiments are extended, while on the other hand the maximum at 77% Zn becomes more obliterated with longer duration of the tests.

The relation to the concentration during the chemical attack is in general similar in the experiments reproduced in Fig. 2 and those of Fig. 3. However, the following difference can be noticed: there are two maxima of attack (see Fig. 2), one immediately after passing the eutectic, the other which represents a maximum at higher zinc contents, has shifted to a concentration of approximately 82% Zn.

In one regard all experiments show the same result, practically no zinc goes into solution between 0 and 17.4% Zn which represents the eutectic composition. This fact evidently proves that—if both metals are crystallized together in the eutectic concentration and if there is only primarily segregated Cd as a second constituent—a protective effect of zinc takes place due to the influence of Cd. This phenomenon can be explained in the following manner: the zinc-crystals in the eutectic are dissolved at first, confirmed by the analysis of the sodium hydroxide, thus producing in the "cadmium-rich" eutectic a surface layer chiefly consisting of Cd which protects the zinc particles underneath this layer.

The constitutional diagram of Zn-Cd is as shown above characterized by a low solubility of the solubility of the solid constituents in each other. It has been proved that this solubility decreases with falling temperatures. According to the present prevailing conceptions on the improvement of metals by additions, an artificial hardening of zinc by small amounts of Cd should be possible by tempering at higher temperatures in the range of homogeneous solid solution, quenching and holding at lower temperature. The limit of improving Cd-Zn alloys is reached at the concentration of the zinc-rich saturated solid solution at the eutectic temperature (96.3% Zn at 236° C.).

Improvement of the Physical Properties

Jenkins[10] has stated in regard to the improvement of the physical properties of zinc by means of additions of cadmium, that an addition up to 2% of cadmium actually improves the physical properties of zinc in the case of cast as well as rolled alloys. In addition to this, he carried out orientating measurements on the possibilities of improving an alloy with 97.5% Zn and 2.5% Cd by annealing

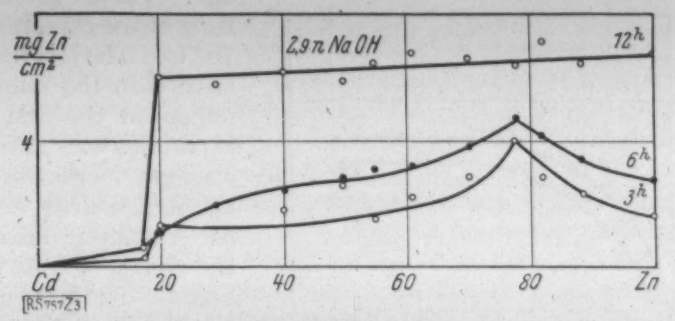


Fig. 3—Chemical Attack of Cd-Zn Alloys by 2.9 NaOH in 3,6 and 12 Hours at 45°C.

at 335° C. for 3 days, by quenching and measuring the change in hardness at ordinary temperature in relation to the storage times. His determinations of Brinell-hardness with a ball of 10 mm. diameter are assembled in Table 3.

A distinct increase of hardness can be noticed in the course of seven days after which a decrease takes place.

Our own alloys employed in the following experiments contained 98% of Zn and 2% Cd. They were prepared from the purest Kahlbaum products, melted in a porcelain crucible and cast into an iron mold preheated to 350° C. From such a cast piece, thirty tensile test pieces could be made. The small ingots of three millimeters thickness were rolled into sheets one millimeter thick. Zinc and zinc alloys can easily be rolled if the speed of rolling is low enough (10 r. p. m. 90 mm. roll diameter) at an initial temperature of 150–200° C. From the rolled material, samples for tensile testing were made with the dimensions shown in Fig. 4 (all dimensions in mm.) thickness 1 mm. The ratio of thickness to width, which according to Martens should not exceed 1:4.5 was chosen 1:10 to save material. The samples were heated at 300° ± 10° C. for an hour and then quickly quenched in ice-water. The change in tensile strength, elongation and hardness in relation to time was determined by means of the universal testing machine of the Losenhausen Company of Düsseldorf-Grafenberg. For control purposes test bars of purest zinc were submitted to the same treatment and broken. After quenching 65 samples were held at room temperature, 45 and 70° ±3° C. The results are reproduced in Tables 4 and 5.

Table 3 Improvement of Cd-Zn Alloys According to Jenkins

Aging time	H 10/500/120	Aging Time	H 10/500/120
0 days	Approx. 45 kg./mm.²	15 days	Approx. 60 kg./mm.²
1 day	Approx. 65 kg./mm.²	2 weeks	Approx. 55 kg./mm.²
7 days	Approx. 63 kg /mm ²	4 months	Approx. 52.5 kg./mm.²

Table 4 Test Results on Improved Cd-Zn Alloys (Stored at 20° C.)

Days after Quenching	98% Zn + 2% Cd σ_B Kg./mm.²	98% Zn + 2% Cd δ %	Pure Zn σ_B Kg./mm.²	Pure Zn δ %	98% Zn + 2% Cd H 2.5/187.5/60
0	14.3	5.7	11.6	7.9	57.2
1	16.0	7.8	11.6	7.8	60.8
2	17.2	9.2	..	...	63.5
3	18.2	9.9	11.5	8.1	64.9
4	18.5	10.4	..	...	65.4
5	18.6	10.8	11.3	8.3	65.0
9	19.1	11.6	11.2	8.3	65.2
15	19.2	11.4	11.3	8.1	64.4
8 weeks	19.0	11.5	..	...	..

In the first column of Table 4 is given the time after quenching; in the second and third column tensile strength σ_B in kg./mm.² and elongation δ in % for the alloys of 98% Zn and 2% Cd, in the fourth and fifth column the values of pure zinc. In the sixth column the hardness determinations of the 98/2 alloy are given. The hardness was determined with a ball of 2.5 mm. diameter and a load of 187.5 kg. with a testing time of 60 sec. The results in every case represent the average values obtained in 3 to 5 single tests. The largest discrepancies of the single results in comparison

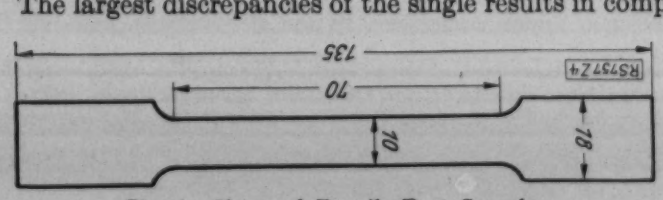


Fig. 4—Shape of Tensile Test Samples

with the average value was ±3% in the tensile test and ±1% in the hardness measurements.

The tensile strength of the improved alloys evidently increases after a fortnight from 14.3 kg./mm.² to 19.2 kg./mm.² and still is 19.0 kg./mm.² after 8 weeks. Elongation rises from 5.7 to 11.5% during storage. The physical properties of pure zinc submitted to the same conditions practically remained unchanged during storage. Table 5 gives the results of the experiments at 70° C. The test bars were treated in the same manner as in the first set of experiments. The tensile strength increases to 18.9 kg./mm.² after 12 hours and distinctly falls off in the course of a further 22 hours. The large increase in elongation is surprising, increasing from 6.0 to 14.5% within 34 hours without reaching the maximum value. The increase in hardness is relatively small in both cases, but pronounced, amounting to 15-20% of the initial value.

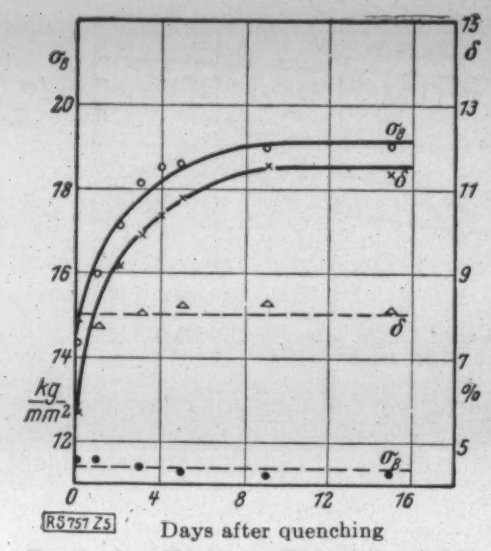


Fig. 5—Age Hardening Procedure of Cd-Zn Alloys (2%Cd) at Room Temperature

Table 5 Test Results on Improved Cd-Zn Alloys (Stored at 70° C.)

Hours after Quenching	98% Zn + 2% Cd σ_B Kg/mm.²	δ %	H 2.5/187.5/60
0	14.6	6.0	48.5
1	16.3	7.9	54.4
2	17.0	9.3	54.7
4	17.7	10.7	56.9
7	18.1	12.4	56.5
12	18.9	13.1	58.0
24	18.4	13.6	57.3
27	18.6	14.1	..
34	18.2	14.5	57.5

In Fig. 5 the course of the improving process at room temperature is reproduced whereas Fig. 6 shows the course at 70° C. graphically. The abscissae for the first case give the time in hours, and in days in Fig. 5. The ordinates give the tensile strength σ_B in kg./mm.² and the values for elongation δ in per cent. The value of the σ_B-curve are represented by circles, those of the δ curve by crosses. In Fig. 5, the curves of pure zinc are broken for comparison whereby the σ_B values and the δ values are given by triangles and by black circles, respectively. It can plainly be seen from the slope of the curve that the mechanical properties of pure zinc are hardly influenced by heat-treatment outlined above.

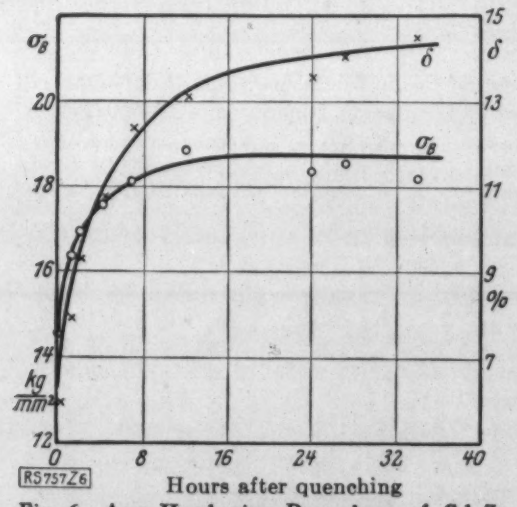


Fig. 6—Age Hardening Procedure of Cd-Zn Alloys (2% Cd) at 70°C.

Obviously the curves take the typical course encountered in age hardening, i. e., tensile strength and hardness of the test pieces increase rapidly immediately after quenching, but rise more and more slowly with longer times after quenching.

[1] J. Jenkins, *Journal of Institute of Metals*, **29**, 239 (1923); **36**, 63 (1926), bibliography.

[2] Benedicks, *Metallurgie*, **7**, 531 (1910).

[3] Benedicks and Arpi, *Zeitschrift für anorganische Chemie*, **88**, 237 (1914).

[4] Petrenko, *Zeitschrift für anorganische Chemie*, **162**, 251 (1927); **167** 411 (1927).

[5] Pierce, Anderson and van Dyck, *Journal of Franklin Inst.*, **200**, 349 (1925).

[6] Freeman, Brandt and Sillers, Bureau of Standards, *Scientific Paper* **522** (1926).

[7] Grube and Burkhardt, "Festschrift der Techn. Hochschule zur Vollendung ihres ersten Jahrhunderts," page 140, Julius Springer, Berlin, 1929.

[8] Glasunow and Matweew, *Intern. Zeitschrift für Metallographie*, **5**, 113 (1914).

[9] The details of the method of investigation may be found under Grube and Burkhardt, see reference 7, page 231.

[10] See reference 1, page 231.

Factors in Production of Sponge Iron

The idea of "direct processes" for the production of iron and steel from the ore has persisted throughout the history of ferrous metallurgy, says the United States Bureau of Mines, Department of Commerce. The production of steel from sponge iron has theoretical advantages over the present-day standard methods, and hundreds of so-called "direct processes" have been proposed or tried during the past century.

Iron oxides, when reduced at temperatures below 900° C. form a dark gray substance, very porous but otherwise in almost the same form as the original particles. In the temperature range of 1000 to 1100° the product is partly sintered but still shows the outlines of the original particles. These products are known as "sponge iron." At temperatures of 1100 to 1200° the metallic iron begins to flow together into a semifused, pasty, porous mass called a "bloom," which can be worked under a hammer to form a product similar to wrought iron; it contains slag inclusions and is too low in carbon to make steel. If the temperature is 1200 to 1300°, part of the iron will fuse enough to absorb more carbon. The dissolved carbon lowers the melting point and still more carbon is absorbed. The melted portion acts as a flux for the unmelted metallic particles until the entire mass becomes a high-carbon fluid known as "cast iron."

Sponge iron was probably the form in which the first iron was recovered from the ores. As early as the eighth century the Catlan forge developed into a low-shaft furnace known as the "high bloomary," in which iron was produced in the form of a pasty mass. In 1340 the first blast furnace was built in Belgium. The greater part of the iron was made into wrought-iron blooms by crude puddling processes. Charcoal was used as the fuel until the latter part of the 17th century when coke was used in England. In 1865 Bessemer built his first converter in England, and within a few years the Siemen's regenerative open-hearth furnace was developed, also in England. Enormous expansion in the metallurgy of iron followed.

In Serial 2955, by Edward P. Barrett, just published by the Bureau of Mines, some important factors in the production of sponge iron are outlined. Iron oxides may be reduced by heating with either gaseous or solid reducing agents, Mr. Barrett points out. The reduction of iron oxides to metallic iron is a step-by-step process. The various steps in both the gaseous reduction process and the ore-solid process are outlined in the paper.

The rate of reduction of particles of iron oxides depends on a number of factors as follows:

Size of particles and physical structure of the oxide; temperature which controls the reaction velocities of deoxidation of iron oxide and the conversion of carbon monoxide from carbon dioxide and carbon; kind, concentration and amount of reducing agent and rate and quantity of heat input.

Ores containing large amounts of gangue are as undesirable in low-temperature and direct processes as in the blast-furnace process, it is noted. In some instances it has been possible to beneficiate the ore prior to reduction. If the physical structure of the ore is such that the gangue cannot be separated from the iron oxides, it will probably be equally difficult to separate the metallized particles from the gangue after the ore has been treated in a reduction furnace. Large percentages of gangue in the ores treated will produce sponge iron high in gangue which will result in large slag volumes in the melting furnace. This will increase the cost of production of steel over that produced from sponge iron low in gangue.

Much has been written concerning the many processes proposed for producing sponge iron and other "direct process" metal. Few writers have emphasized the fact that iron produced in low-temperature and so-called "direct processes" contains much of the sulphur originally contained in the raw materials from which it was produced. In some experiments conducted by the Bureau of Mines both high- and low-sulphur coals were used. The various products from the furnace were called furnace product, concentrate and tailing. Furnace product was the material as removed or discharged from the furnace. This material passed over a magnetic separator produced concentrate and tailing. The concentrate contained nearly all of the magnetic material, some carbon, and gangue from the ore. The tailing contained the non-magnetic material. With ore containing 0.18 percent sulphur and a coal about as low as can ordinarily be obtained (0.54 percent sulphur), the concentrate contained about the same amount of sulphur as was present in the original ore. If coal

(*Continued on page 300*)

The Third Open Meeting of the Metallurgical Advisory Board, Pittsburgh, Pa.

This meeting was opened at 10 a.m., October 18, 1929, in the auditorium of the Bureau of Mines with Dr. John Johnston, Director, Department of Research and Technology, United States Steel Corporation, presiding. In his welcome address, F. N. Speller, Director, Department of Metallurgy and Research, National Tube Company and Chairman of the Metallurgical Advisory Board, praised the active cooperation of the several steel companies where open-hearth steel making reactions are being studied.

Dr. C. H. Herty, Jr., Physical Chemist, Bureau of Mines and Dr. V. H. Krivobok, Metallurgist, Bureau of Metallurgical Research, Carnegie Institute of Technology, reported on Abnormality in Case-Carburized Steels. This work is published in the form of Cooperative Bulletin 45,[1] Mining and Metallurgical Investigations.

In his discussion of this report, Dr. Oscar E. Harder, Professor of Metallography, University of Minnesota, pointed out the difficulty of picturing the movement of the cementite particles after precipitation at the Ar_1 temperature through the rather wide fields or through a rather large distance in space to form the massive cementite in the comparatively short period of time which is available during the usual rates of cooling in these tests. Harder prefers to attribute the abnormal structures to the formation of cementite at abnormally high temperatures for the particular carbon contents to such an extent that it may then become supersaturated with reference to ferrite and thus deposit some ferrite adjacent to the massive cementite. The reaction, then, should go to the simultaneous precipitation of ferrite and cementite giving some rather well-formed pearlite. Migration during the eutectoid reaction very likely plays some part in the formation of more massive cementite particles and the less well-laminated pearlite. The report was also briefly discussed by W. J. Merten, Metallurgical Engineer, Westinghouse Electric & Manufacturing Company.

The progress report on the preparation of Iron-Carbon-Manganese alloys next occupied the attention of the meeting. Dr. F. M. Walters, Jr., Director, Bureau of Metallurgical Research, Carnegie Institute of Technology, described the design and construction of a high frequency induction furnace for melting under controlled gas atmospheres. The difficulties encountered in this work were described. It was decided to melt in an atmosphere of argon, as analysis showed that argon was not absorbed by electrolytic iron. In the case of manganese alloys no satisfactory method for ascertaining the presence or absence of argon is known. Walters reported on the making of 4 iron-manganese-carbon alloys in the above furnace under argon: 0.2% C, 7% Mn; 0.2% C, 10% Mn; 0.4% C, 7% Mn; 0.4% C, 10% Mn.

Microscopic examination of these melts showed them to be remarkably free from non-metallic inclusions. As cast, the alloys had a hardness of about 40 on the Rockwell C-scale; this is little changed by forging. No pronounced effect is caused by quenching in brine or tap water, normalizing or annealing. These alloys are "air hardening" and are remarkably tough.

Dr. James B. Friauf, Physicist, Bureau of Metallurgical Research, described a furnace for the distillation purification of manganese. The original furnace for this purpose described last year, although satisfactory in most respects was too small. A more powerful diffusion pump was installed to be used with the new furnace and made it possible to maintain an appreciably lower vacuum than in the original furnace in spite of the greater charge. The operation of the new furnace was described.

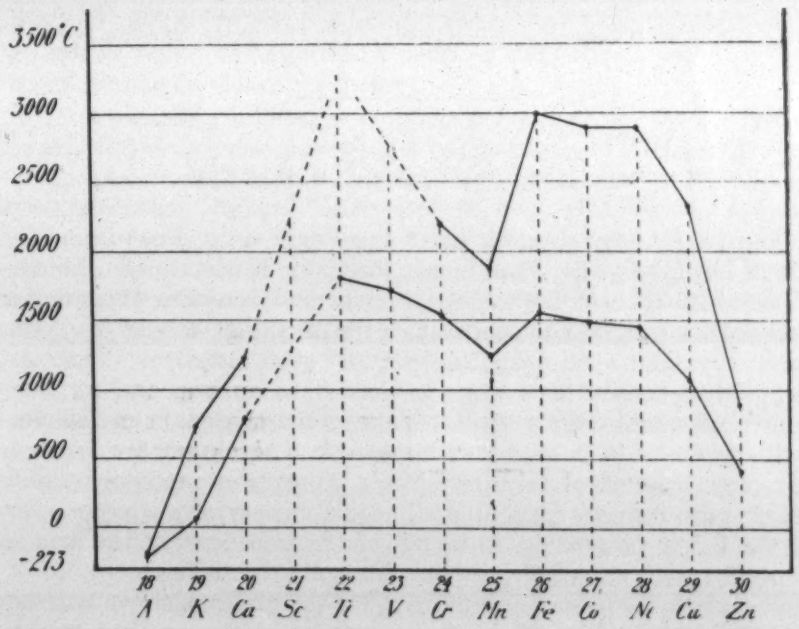
Dr. Krivobok rendered a report of the work on special steels. To date the work has been strictly fundamental in nature. This does not mean that the work is devoid of the practical applications. America, while rich in some elements, depends on import for the others. The work "On the Constitution of High Manganese Steels" has already been published in the *Transactions of the American Society for Steel Treating*. At present the critical points in austenitic manganese steels, partially decomposed under certain conditions of treatment, are being determined with a view of determining possibilities for further changes in properties. From the work so far completed, it seems that critical points depend almost entirely on the previous treatment of decomposition.

A preliminary exploration was made of the chromium steels containing 0.10 to 0.60% carbon and 16 to 35% chromium. This work is published as Preprint 18 (1929), Eleventh Annual Convention of the American Society for Steel Treating.

Due to the interest in the so-called 18–8 stainless irons, it is proposed to manufacture a considerable quantity of a pure iron-chromium alloy and with this as a basis a series of alloys containing increasing additions of carbon and nickel. The physical properties will be studied, especially at high temperatures.

In the discussion of these reports, Dr. John Johnston pointed out the importance of research workers having a source of supply of magnesium oxide crucibles, rather than each worker being forced to make his own as needed. He also expressed the hope that this work might induce more "good young men to choose metallurgy as a profession, instead of chemistry." Dr. Zay Jeffries emphasized the importance of impurities on metals, using as an example the manufacture of tungsten for electric lamps. Louis Jordan, Chief, Section of Chemical Metallurgy, Bureau of Standards, suggested that in the work on the iron-carbon-manganese alloys, the investigation on the utilization of materials be delayed until the end. Dr. P. Brace, Metallurgical Engineer, Westinghouse Electric & Manufacturing Company, pointed out that the reports show how the metallurgist has brought together the various sciences. He predicted that the furnaces of the future will approach machine tools and that vacuum melting will be used for special steels in the near future; it has already been applied abroad.

N. Zeigler, Westinghouse Electric & Manufacturing Company, reproduced by means of a slide a curve[2] which explains why manganese and zinc can be so easily vacuum distilled.



Melting Points and Boiling Points of Elements. The Combining Forces between Atoms Are Shown Related to the Positions of Melting and Boiling Points

G. St. J. Perrot, Superintendent, U. S. Bureau of Mines Experiment Station, Pittsburgh, opened the afternoon session devoted to "The Physical Chemistry of Steel Making" with a brief résumé covering the history of the cooperation of the U. S. Bureau of Mines, Carnegie Institute of Technology and the Metallurgical Advisory Board.

The report on the physical chemistry of steel making was divided into two parts: 1, Fundamental Studies in the Laboratory; 2, Plant Research in the Open-Hearth. The laboratory studies included the solubility of iron oxide in steel and various kinds of slag, the effect of commercial deoxidizers on these solubilities, the viscosity of slags at various temperatures, and the chemical and microscopical identification and analyses of inclusions and gases in steel. In discussing the laboratory work Dr. Herty stated that the question of the amount of iron oxide which will dissolve under various kinds of slags is of foremost importance. He announced new methods for measuring the amount of non-metallic inclusions in steel. He reported on the use of these new methods for reanalyzing and recomputing old data and showed how former unexplained and puzzled discrepancies could be explained.

[1] Copy can be obtained from John D. Beatty, Carnegie Institute of Technology, Pittsburgh, Pa. Price, $1.00.

[2] *Stahl und Eisen*, May 9, 1929, page 603.

In order to obtain more accurate data on the deoxidation of silicon, polished samples of the steel were examined for inclusions under a micrometer microscope and each globule was measured and classified as to its nature. Duplicate slag counts made on various planes of a metal sample gave remarkably concordant results. In checking over a large number of samples, more visible oxygen was found than given by chemical analysis. This visual determination method, and a new electrolytic method of segregating non-metallic inclusions,[3] not only form a new basis of appraising past work on slag-metal reactions, but will also be used in future work on the synthesis of inclusions in the laboratory and their identification in steels.

Plant studies in removing iron oxide from steel by the use of silicon have shown that unless a considerable amount of manganese oxide is present in the steel at the time of the silicon addition, it is extremely difficult to remove the products of deoxidation. Failure to remove the deoxidation products results in dirty steel, with the evils resulting thereform. The important influence of time for cleaning has been very clearly brought out and if silicon alone is used as a deoxidizer an extremely long time is necessary to clean the steel.

Microscopic work on samples taken from furnaces varying in capacity from 40 to 250 tons has made it possible to calculate the speed of cleaning of the steel with considerable accuracy. The microscope is thus useful not only in determining what is in the steel in the solid state but also in determining what will happen to the steel in the liquid state. The amount of iron oxide carried in the steel has been correlated with the composition and physical characteristics of the slag, and methods of controlling the iron oxide content of the steel by controlling the slag have been pointed out. The answer to making clean steel apparently lies in having the proper kind of slag, adding the proper amount of deoxidation at the proper time. Failure to take into account any of these three factors very generally leads to dirty steel.—Richard Rimbach.

[3] Cooperative Bulletin 44, "Theoretical Considerations in the Electrolytic Determination of Non-metallic Inclusions in Steel." Price, 50 cents.

Alloys of Iron Research

The Iron Alloys Committee of the Engineering Foundation, of which Dr. George B. Waterhouse, Professor of Metallurgy, Massachusetts Institute of Technology, is chairman, is now actively under way with a program of cooperative research that should be of the greatest value to the American iron and steel industry. The subject of this committee's work is basic data on iron and its very numerous combinations with other metals and certain metalloids. Extensive as is the use of iron in this "iron age" very few persons have ever seen absolutely pure iron. Many thousands of tons of nearly pure iron are used annually for a variety of purposes. By far the larger proportion, however, of the iron used in the arts is combined with other substances. First are the millions of tons of carbon steels for frames of buildings, for the plates of ships, boilers, tanks and pipes, for rails in the steam and electric railroads and for multitudinous other things. Iron castings account for many other thousands of tons. Besides these common forms increasing quantities of so-called alloy irons and alloy steels are being used in automobiles, aircraft, machinery, bridges, household utensils and other objects beyond enumeration.

Our industries and engineers have scarcely more than begun to apprehend the possibilities of alloy irons and alloy steels. Nevertheless, progress has been rapid in recent years. Much more information is needed by both producers and users. To meet these needs a great deal of information is being found in laboratories of industries, governmental bureaus, universities and other institutions in several countries. It is finding its way into thousands of publications in half a score of languages. To many busy men, unfortunately, much of the information is not available, for obvious reasons. There is wasteful duplication of effort and expense and loss of time by the larger establishments that seek all useful information at whatever cost.

The Iron Alloys Committee consequently has accepted as its first duty the very large task of culling from the voluminous literature the essence of useful knowledge and putting it into forms convenient for use by researchers, technologists, engineers and superintendents. Repeatedly, foremost technical leaders in the industries and research institutions urged this work as the greatest possible aid which Engineering Foundation, on behalf of the engineering societies, could give to the progress of the iron, steel and related industries in developing alloy irons and alloy steels. Notable progress is reported from other countries. The United States of America must keep in the front line. It is planned to print the results of this review of the literature in monographs for the research men and in manuals for engineers and superintendents.

For the second part of its undertaking, the Iron Alloys Committee will aid, promote and organize researches for new basic information about pure iron and its combinations with other substances. It will not attempt to discover or devise commercial alloys; that is the business of the laboratories in the industries. Rather the Committee will seek those underlying facts which will be necessary to all the industrial metallurgical laboratories.

Dr. George B. Waterhouse

To conduct this extensive and important project a committee of distinguished metallurgists has been selected from the several sectors of the field. Engineering Foundation now announces the membership of the Iron Alloys Committee.

Dr. George B. Waterhouse, *Chairman*, Professor of Metallurgy, Massachusetts Institute of Technology
Dr. George K. Burgess, Director, National Bureau of Standards; Louis Jordan, of the Bureau, alternate
Mr. Scott Turner, Director, U. S. Bureau of Mines; Dr. Charles H. Herty, Jr., alternate
Mr. R. E. Kennedy, Technical Secretary, American Foundrymen's Association
Dr. H. W. Gillett, Director, Battelle Memorial Institute
Dr. Bradley Stoughton, Director, Metallurgical Engineering Department, Lehigh University
Mr. Jerome Strauss, Chief Research Engineer, Vanadium Corporation of America
Mr. T. H. Wickenden, Metallurgical Engineer, The International Nickel Company
Dr. John A. Matthews, Vice-President, Crucible Steel Company of America.

To aid the Iron Alloys Committee, Engineering Foundation has assurance of cooperation from the American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers, American Society of Civil Engineers, American Institute of Electrical Engineers, American Iron and Steel Institute, Society of Automotive Engineers, American Society for Steel Treating, American Society for Testing Materials, National Bureau of Standards, U. S. Bureau of Mines, numerous corporations in the metallurgical industries and several universities. There are encouraging indications that foreign cooperation also may be arranged in due time.

Annual Autumn Meeting of The Institute of Metals, Düsseldorf, September 9–12, 1929

This was the first meeting of the Institute to take place in Germany and was the result of an invitation of the Deutsche Gesellschaft für Metallkunde.

The Eighth Autumn Lecture was delivered by Dr. A. G. C. Gwyer on "Aluminium und seine Legierungen" (Aluminum and Its Alloys) in German. The speaker discussed some of the more important investigations in the field of aluminum alloys carried out in recent years. Special attention was directed to the out-standing characteristics of these alloys more particularly from the points of view of soundness and resistance to corrosion. The more recent accomplishments were considered. Of recent years the question of heat treatment of aluminum alloys has received considerable attention; Dr. Gwyer therefore devoted a considerable portion of the lecture to age hardening. He concluded with a short account of the recent results of X-ray spectrography, which he considers of very great importance, and one which is likely to yield very valuable and practical results in the near future.

On Tuesday, September 10th, Dr. Walter Rosenhain, President of the Institute opened the Convention with a welcome to the members and their guests. He announced the election of Dr. Gustav Tammann to honorary membership in the Institute for his meritorious work in the development and promotion of metallography.

Dr. Rosenhain read the first paper entitled "Some Methods of Research in Physical Metallurgy," in which he described the methods developed in recent years, and particularly in the Metallurgy Department of the National Physical Laboratory for the study of metals, especially in connection with the determination of equilibrium diagrams. The methods of determining and recording thermal curves, resistivity-temperature and dilation-temperature curves were discussed in detail, an account was given of a novel form of electrical dilatometer making use of measurements of capacity of a small condenser which is varied by the dilation of the sample. The measurement of this capacity is made by means of oscillatory circuits utilizing thermionic valves, and the resulting graph is plotted by means of an electrical "thread recorder." Reference was also made to the development of optical pyrometry, and a novel method of securing black body conditions, by sighting upon the interior of a gas bubble blown in a mass of molten metal, was described. The applications of the study of structure by means of the microscope and of crystal lattices by means of the X-ray spectrometer were discussed in regard to their bearing upon the equilibrium diagram. Finally, stress was laid upon the importance of securing accurately known composition and the highest possible degree of purity in the metals and alloys used for investigations of this kind. Reference was made to the methods for producing metals of high purity, and the development of special refractories for that purpose, which have been developed at the National Physical Laboratory.

The "Methods of Research in Metallography" were discussed by Dr. G. Masing of Berlin. He pointed out that the experimental methods are not sufficient for accurate work and must be improved in precision and amplified (especially X-ray technique). The most important improvement required is the development of a method for the rapid attainment of equilibrium in an alloy. Besides the establishment of equilibrium diagrams the study of constitution nowadays demands an investigation of the condition of alloys far removed from the state of equilibrium; the theoretical and experimental aspects of this problem were considered.

In physical metallography the greatest interest is evinced in the study of plastic deformation and its attendant phenomena: deformation, hardening, recrystallization, etc. The importance of using precise physical methods in order to make further advances in this field was emphasized.

A paper on "A Dilatometric Study of Some Univariant Two-phase Reactions," by P. Chevenard, A. M. Portevin and X. F. Wache was presented on Tuesday, September 10th. By dilatometric methods, the authors studied the reactions taking place in quenched aluminum-copper and aluminum-silicon alloys, when annealed at various temperatures. A new reaction was detected and the speed of precipitation as influenced by temperature was studied. The boundary of the two-phase field on the iron side of the Fe–Ni–Cu system was determined.

Dr. M. Haas (Aachen) and Dr. Denzo Uno (Kyoto) reported on "An Improved Differential-Dilatometer." The paper describes improvements of Chevenard's optical differential-dilatometer, accomplished by mounting the apparatus on a triangular rail, by using one dilatometer tube instead of two, and by replacing the spring that holds the mirror by a magnet coil arrangement. Provision was also made for working in any special atmosphere, and for sketching purposes.

In a paper entitled "The Open-Air Corrosion of Copper. A Chemical Study of the Surface Patina," W. H. J. Vernon (Teddington) and L. Whitby (Teddington), showed that in general, the green patina consists essentially of basic copper sulphate. An exception to this is the product from a purely marine atmosphere, in which basic copper chloride predominates; where urban and marine conditions coincide, however, then basic sulphate in the product greatly predominates over basic chloride. Contrary to the general belief, basic copper carbonate enters only to a minor extent into the composition of the product, even in rural districts remote from sea and town. Sulphur compounds, derived from products of combustion and disseminated by wind, are the most potent agents in the development of patina. The underlying metal, after long periods of exposure, shows remarkable freedom from pitting. With the exception of lead, which tends to accumulate in the product, the impurities usually present in the metal have no appreciable effect on the composition or appearance of the patina.

"Studies on the Crystallization of Gold from the Liquid State," by C. O. Bannister, dealt with the crystallization of gold from the liquid state, and gave different methods of preventing undercooling and "flashing." It illustrated the formation of straight boundary lines by the interference of radial growth from two, three and four nuclei, and the formation of curved boundary lines by retardation of growth from one center.

In the final paper of the Tuesday session "The Creep of 80:20 Nickel-Chromium Alloy at High Temperatures," by A. Glynne Lobley (Birmingham) and C. L. Betts (Stockport), Mr. Lobley gave the progress of experiments in the form of abridged graphs. Wires 0.018, 0.0625 and 0.25″ thick, were subjected to tensile stresses of 50, 100, 200 and 400 lb./in.^{2} at temperatures of 700, 800, 900 and 1000° C. for a period of approximately 4000 hr., and accurate measurements made daily of the movements. At the highest temperature there was no evidence of creep stress limit. The rate of flow was found to be dependent on the diameter of the wire as well as on the other factors.

The Wednesday session was opened by Dr. W. J. P. Rohn (Hanau-am-Main) who presented a paper entitled "The Reduction of Shrinkage Cavities and Vacuum Melting." The construction of water-cooled copper molds, used in connection with vacuum melting furnaces were described. Shrinkage cavities, it is shown, may be totally avoided if melting and freezing are performed in an electrically heated melting furnace in a crucible of the shape of a finished ingot, and, after melting and refining is completed, the current is cut off gradually from the bottom with a well-controlled speed.

"Progress in Electric Furnaces for Non-Ferrous Metals," by M. Tama (Eberswalde), discussed the whole field of modern induction furnaces for melting, heat treating and annealing.

The paper "Pinholes in Cast Aluminium Alloys," by N. F. Budgen (Birmingham), considered the causes of pinholes in sand-cast aluminum alloys to be: the gas evolution at solidification, the shrinkage during solidification, the composition of the alloy and the general casting conditions. Means for preventing pinholes were described.

An investigation of the Council of the British Non-Ferrous Metals Research Association dealt with some of the metallurgical results of the research on "Copper Locomotive Stay Rods" which the Association is carrying out on behalf of the British Railways. The paper "Properties of Locomotive Firebox Stays and Plates" was prepared by O. F. Hudson, T. M. Herbert, F. E. Ball and E. H. Buchnall (all of Birmingham). The authors showed that while wastage is primarily dependent on oxidation of copper, the severer forms are caused by the action of water leaking between stays and plate, so loosening the hard and adherent oxide scale of arsenical copper. A great increase in the amount of oxidation is caused by the presence of chlorine, hydrochloric acid or sulphur dioxide in the firebox atmospheres. Preliminary results of a study of the softening and elastic properties of cold-worked copper containing small percentages of other elements are given. It is shown that as small a quantity as 0.05% of silver results in an extremely beneficial influence.

The "Effect of Temperatures Attained in Overhead Electric Transmission Cables" is presented in a paper by A. v. Zeerleder (Neuhausen) and P. Bourgeois (Neuhausen). The increases of temperature produced by a current of electricity in transmission

cables made, respectively, of copper, pure aluminum, steel-aluminum and Aldrey were measured. Cables consisting of these materials were submitted to temperatures lower than the usual annealing temperatures for periods ranging over several months up to one year, and the effect on the mechanical properties was examined. It was found that Aldrey is not affected by temperatures which will seriously diminish the tensile strength of copper. Cables consisting of aluminum alloys having undergone previously an appropriate heat-treatment—such as Aldrey—are thus able, in spite of their lower electrical conductivity, to be loaded with higher current densities than copper cables without danger of slow annealing.

"The Results of Seven Years' Exposure to Air at Birmingham" was presented by J. Newton Friend (Birmingham) as part II of a paper "The Relative Corrodibilities of Ferrous and Non-Ferrous Metals and Alloys." Fifty-four bars of ferrous and non-ferrous metals were exposed to air on the roof of the Birmingham Central Technical College for seven years, and an account is given of the 17 non-ferrous bars. The metals examined included tin, lead, nickel, zinc, aluminum and various coppers and brasses. All resisted corrosion much more efficiently than the wrought iron and carbon steels. Nickel proved less resistant than copper. Aluminum ranked with lead, tin and stainless steel in offering a very high resistance to corrosion. The influence of arsenic on copper is discussed.

A description of "Idiomorphic Crystals of Cuprous Oxide in Copper" is given in a paper by C. Blazey (Port Kembla, Australia). The copper contained 0.43% oxygen, after heating for a long time at a temperature above 800° C.—CARL KUETTNER.

First Meeting of Iron Alloys Committee

Sept. 25, 1929

The first meeting of the Iron Alloys Committee was called to order by Chairman George B. Waterhouse in the Board Room of the American Institute of Mining and Metallurgical Engineers at one-thirty p.m. with all members present save one, who was prevented by illness. There are nine members. The Committee made effective progress in discussing organization of its project, general policies and program, candidates for Editor-in-Chief, and cooperation with other bodies, Professor Bradley Stoughton, of Lehigh University, member of the Committee, gave an interesting and valuable report on the work he has been carrying on for about a year and a half on the literature of iron and silicon, supplemented by laboratory research.

On invitation, Professor V. N. Krivobok, of Carnegie Institute of Technology, was present and described the important research on iron and manganese which has been carried on in the Institute's laboratories since October 1928. Some work had been done also on the literature.

Besides their intrinsic value, these two researches are helpful to the Committee as examples of the two kinds of work which will occupy its attention. Engineering Foundation made small contributions to the financial support of these researches.

The Committee plans to obtain a list of laboratories engaged on work in which it may be interested and of the men in charge.

The dinner which followed the meeting was attended by thirty-one persons, including members of the Iron Alloys Committee, officers of the American Iron and Steel Institute, the A. I. M. E. Advisory Committee, a number of special guests, and members of Engineering Foundation. Chairman Porter, of the Foundation, as host, presided and introduced Chairman Waterhouse, of the Committee, who gave a brief outline of the purposes and plans of the Committee and introduced the seven other members who were present. Mr. Dinkey reported for the Committee on Ways and Means. Secretary Clarke, of the American Iron and Steel Institute, told of the interest and cooperation of that organization. Mr. Reynders, as Chairman of the General Conference on Alloys of Iron Research, emphasized his conviction of the importance of the project and the necessity for expeditious progress for the benefit of the iron and steel industries. Messrs. Becket, Dunn, Mathews, Wadhams and others joined in the discussion.

Several speakers predicted that the work, if well done, would go on indefinitely because of the value to industries and engineers of knowledge about iron and its combinations with other substances and the many facts yet to be learned. Mr. Stillwell expressed the opinion that it would be very profitable to make the critical review of the present literature in half the time proposed if it were possible to provide the funds and obtain enough competent men, so that, as Mr. Stuart suggested, industries and engineers might soon have a statement of what is now known and thus avoid duplication of searches of the literature and of researches in laboratories.

(*Continued from page 296*)

contains more sulphur than the ore, the latter absorbs sulphur from the coal during the reduction process. In the case of an ore with 0.15 percent sulphur and a coal with 4.48 percent sulphur, the sponge iron concentrate contained eight times as much sulphur as the original ore.

Ores containing such high percentages of sulphur would not be used to produce sponge iron for conversion into iron or steel. Such ores can be used to produce sponge iron for use as a precipitant in copper and lead leaching processes.

The average of results obtained in a series of 20 tests in externally-heated retorts showed that over 60 percent of the sulphur in the charge was present after reduction had been completed. The ore contained only traces of sulphur. The coal contained 0.80 percent sulphur.

The sulphur content of these sponge-iron concentrates was much higher than the tolerant limit of 0.05 percent sulphur in pig iron. It is not feasible to decrease the sulphur in such high-sulphur sponge iron to within the tolerant limit by refining in the open-hearth furnace. The sulphur content of such high-sulphur sponge iron can be decreased to within the tolerant limits by refining in the electric furnace. The cost of removing sulphur by refining in the electric furnace increases as the sulphur content increases. Exact costs are not available.

Use of Binary Alloys for Deoxidizing Steel

The formation of non-metallic inclusions resulting from the reaction of iron oxide in liquid steel with certain deoxidizing elements is one of the major problems at the Pittsburgh Experiment Station of the United States Bureau of Mines, Department of Commerce, in cooperation with Carnegie Institute of Technology and the Metallurgical Advisory Board.

The materials first studied were the most commonly used single deoxidizers such as manganese, aluminum and silicon. This work involved the identification of the different types of inclusions formed by varying the additions of each deoxidizer and was found to be valuable in the determination of the degree of deoxidation with each element. It is believed that the desired inclusions should have a low melting point and surface tension so as to readily flux with one another. They will then form large particles and on rising to the slag surface, be eliminated from the metal bath.

Work of this nature has indicated that aluminum reacts with iron oxide to a greater degree than silicon, and silicon more than manganese.

With this latter point in mind it can be easily seen that a large number of difficult problems present themselves in the use of such binary deoxidizing alloys as manganese-silicon, silicon-aluminum and manganese-aluminum. Varying grades of these three alloys are being manufactured and used as deoxidizers at the present time.

Such alloys are being studied by this section and the results obtained indicate that the following considerations must be held in mind during the addition of any binary deoxidizing alloy to steel:

1. The stronger deoxidizer will react more rapidly than the weaker and will form a larger amount of its oxide. If the steel is to be killed, exactly the right amount of the alloy must be added so that the oxides of both the weak and the strong deoxidizing elements are formed. Such precise additions are impractical from the manufacturer's standpoint since this would necessitate an analysis for iron oxide which could be made in a few minutes. At present this is impossible.

2. The amount of alloy added and the ratio of one element to another in the alloy would have to be correlated in such a manner as to form inclusions having a desirable composition.

None of the binary alloys studied by the Bureau of Mines was found to give the type of inclusion desired and it appears that the proper use of two deoxidizers is first to add the desired amount of the weak deoxidizer (such as manganese), allowing its oxide to form, and then, through the addition of the stronger deoxidizer, an inclusion can be formed which contains an appreciable amount of each oxide.

If the steel is to be incompletely deoxidized, the inclusions will contain some iron oxide along with the other two oxides and the chances are more favorable for the formation of fusible inclusions which can be eliminated. Work of this nature will be done in the future.

Book Reviews

Creep of Steels at High Temperatures. By F. N. NORTON. McGraw-Hill Book Co., Inc., New York. 83 pages, 6 × 9 1/4 inch. Price, $3.00.

As valuable as this contribution may be for our knowledge of the properties of steel at higher temperatures, the reviewer cannot help questioning the necessity for this investigation appearing in book form. In books, we are accustomed to being informed on the important relations of problems. They are missed in this case, because the investigator gives only the results of his own tests.

In the described Babcock and Wilcox creep testing apparatus, three furnaces, each containing six samples, were employed for the investigation. The extension of the specimens was measured with an accuracy of 0.0001 of an inch. The loads were increased after every 400 hours. Only the higher temperatures above 1000° F., that is to say, temperatures of 1000°, 1100°, 1200°, 1350° and even 1500° F. for two austenitic steels were employed. In the diagrams the stresses are given for a life of 100,000 and 10,000 hours, respectively, with 1 percent elongation.

Three different groups of steels were investigated:

(1) Five austenitic chromium-nickel-silicon steels.
(2) Five chromium stainless steels.
(3) Seven steels of most different composition with a pearlitic structure in the annealed condition.

Among the results, the fact that austenitic steels have the highest values of creep resistance, may be especially mentioned. The values are about 10 times those of low carbon steels at the same temperature. These results were to be expected due to our present knowledge of the physical properties of γ-iron. In this respect the investigator is in accordance with the simultaneously published results of German investigations (E. Houdremont-V Ehnecke, *Archiv für das Eisenhüttenwesen*, July, 1929, pages 49–60), which pointed out similar facts. More detailed discussion of this particular point would have been of value. The discussion of the results seems to be a weak point of the investigation. The work of Norton would be of still greater value, if the given bibliography, which covers the most important investigations on this subject, had been discussed and compared in more detail with his own results.

As long as do not have a sufficient number of values for the creep resistance according to these tests over a long test time, the shortened methods of investigation, shortened creep tests as well as even the determination of the tensile strength in the hot condition cannot be overlooked in judging the suitability at elevated temperatures.—G. NEUENDORFF.

A Manual of Fire Assaying. By CHARLES HERMAN FULTON AND WILLIAM J. SHARWOOD. McGraw-Hill Book Co., Inc., New York, N. Y. 268 pages, 59 figs., 58 tables. 3rd Edition. Price $3.00.

This edition, in which Dr. Sharwood has joined Prof. Fulton in co-authorship, is thoroughly revised, in part rewritten and contains considerable new material. In particular this applies to the chapters on "Assay Furnaces and Tools," "Reagents," "Parting and Inquartation" and "The Assay of Platinum and Related Metals." Considerable detail is devoted to various types of assay balances, their principles and functioning. Several changes are noted in melting points, such as litharge 884° C. instead of 904° C., $CaCO_3$ begins to give off CO_2 at 800° C. instead of 700° C. Magnesia cupels consisting of about 90% MgO and 10% impurities are receiving more and more attention. Analyses of several of these Patent or Magnesia cupels and cupel material are given. Portland cement cupels are satisfactory only when the mixing water is carefully measured. Cupellation in different types of cupel materials is outlined. The typography and spacing in this edition are improved. The book is well written and is an excellent text book for the student of assaying and for the commercial assayer.—W. H. BOYNTON.

Bibliography of Crystal Structure. By JARED KIRTLAND MORSE. University of Chicago Press, Chicago, 1928. 18 + 164 pages. Price, $3.00.

This is a paper bound pamphlet which describes the X-ray equipment of the courses of instruction in crystal analyses at, and the crystal structure investigations being carried on in the Crystal Structure Laboratory of the University of Chicago; contains reprints of several short articles from that laboratory, chiefly on structure of organic compounds, and gives a bibliography of references to publications on crystal structure through 1927. There are perhaps 1800 references in the bibliography arranged by years, and, under each year, alphabetically by authors. The user would have to make his own arrangement by subjects. Many references to the crystal structure of metals and alloys are scattered through the bibliography, but the metallurgist will not find this bibliography as easy to use as that of Clark on page 106 of the September issue of this journal.—H. W. GILLETT.

The Engineering Index, 1928. Vols. I and II. American Society of Mechanical Engineers, New York, N. Y., 1929. 2091 pages. Price, $115.00.

The Journal of the Institute of Metals. Vol. 41, 1929, No. 1. Published by the Institute of Metals, 36 Victoria St., London, S. W. 1, 825 pp.

Twice a year "J. I. M." comes out, and twice a year we feel that our British non-ferrous friends are doing a very fine job. That the work of the British Institute of Metals is appreciated outside of Great Britain is evidenced by the fact that of the 2000 members, the United States has 276, Germany 88, Japan 79, France 36, Sweden 16, Russia 13, Norway 12, Spain 11, Czecho-Slovakia, Holland and Italy, each 10. Manchuria, China, Iraq and various other countries are represented too. Apparently, Greenland is the only place not represented!

The volume has 360 pages of original articles, several, as usual, being from the National Physical Laboratory, including one by Miss M. L. V. Gayler and G. O. Preston on "Age Hardening of Aluminum Alloys." Of interest to X-ray workers is Miss C. F. Elam's summary of the X-Ray Investigations on Alloys 1921–28, in which the lattice structures of metals and alloys are tabulated with cross references to a bibliography of 80 titles. The May lecture by Sir Oliver Lodge on "States of Mind Which Make and Miss Discoveries" will afford interesting relaxation to any metallurgist.

Among the original articles are those on recent developments in electric furnaces, on large kettles for lead refining, on testing electrodeposits on Al, several articles dealing with Zn, general articles on work-softening and on eutectics, detailed articles on Zr alloys, Mg-Zn, Cd-Ag, one on brittleness in arsenical Cu, and a historical note on Ag content of ancient Pb.

Useful as these original articles are, the 300 pages of abstracts on non-ferrous subjects, by a staff of 30 competent reviewers will be the part most often consulted.

Not much of value that appears in any language gets by without mention in these abstracts, the main difficulty being that they are necessarily somewhat delayed in a publication that only comes out twice a year. And when one has forgotten what volume of "Jim" he saw an abstract in, he is anxious to have the next ten year index, which must be about due.

The Book Reviews are also well done, and really indicate what is in the books, and what they amount to; if the reviewer thinks a book is superficial, or not worth its price, he doesn't hesitate to say so. A good index completes the volume.

Within its broad field of non-ferrous alloys, "Jim" is an indispensable source of information. The reviewer's back volumes have had a good deal of handling, and the binding stands the gaff.—H. W. GILLETT.

Roentgenographie des Eisens und Seiner Legierungen. By C. Neuburger. Ferdinand Enke, Stuttgart, 1928. Paper, 6½ × 10 inches, 124 pages. Price, 3.75 R. M.

Of the different books treating investigations of metallic materials by means of X-rays the present volume is one of the outstanding as it is confined solely to iron and its alloys. The results of the numerous tests are clearly tabulated and the results of the author's own observations have also been included. In the introduction, the methods of metal and alloy research and the structure of solid solutions are discussed; a chapter is devoted to allotrophy of iron. Further, the behavior of the allotropic modifications of the iron towards carbon and the other alloying constituents is discussed in detail. The tabulation of the data on crystal lattices is especially important. The work is concluded with a bibliographic index in this field. This book can be recommended to every metallurgist.—Richard Rimbach.

"Applied Inorganic Analysis." By Dr. W. F. Hillebrand and Dr. G. E. F. Lundell. John Wiley & Sons, Inc., New York, 1929. Cloth, 5 ½ × 9 inches, 929 pages. Price, $8.50.

This book reflects the tendencies of the present-day chemist to revert to the painstaking analyses of the last decade for the greater accuracy demanded by modern methods of testing materials, but in doing so, to take advantage of the new labor-saving laboratory apparatus, new mechanical aids for saving time, the new theories of hydrogen-ion concentration, solubilities, new chemical reagents of higher degrees of purity, colorimetric, nephlometric, spectrographic and electrolytic methods of analysis.

It is somewhat novel in its treatment of the subject. One might expect from its title that it contained a series of specific methods for the analysis of the various materials of commerce. Instead of this, it treats of the general principles underlying "the quantitative preparation of a compound, or solution, that contains nothing that is not taken care of in the calculation on which the determination is based."

The procedures recommended are based on the life-long experience with rock and mineral analyses of Dr. Hillebrand and the researches of Dr. Lundell and his co-workers on the analysis of the standard analyzed samples of the U. S. Bureau of Standards. Numerous tables of physical constants, results of analyses, descriptions of instruments and apparatus are found throughout the text.

It is divided into four parts. Part I deals with the physical equipment, apparatus and reagents for the tests and a detailed description of the technic of analysis. Part II treats of the actual methods and technic to be used in determining the various chemical elements, including many of those rarer elements which are just coming into commercial importance. Parts III, IV and V treat of the analysis of silicate and carbonate rocks, glass and refractories. The indexing, author and subject, is very good.

The book is essentially a compilation of the methods of analysis as published by the U. S. Geological Survey and the U. S. Bureau of Standards, but does contain many new facts. Its detailed and almost encyclopedic treatment of the subjects covered, warrant the book being made the nucleus of a library on Analytical Chemistry for both the chemist and the materials testing engineer. While differing in nature and scope, it supplements the "Book of Standard Methods" of the American Society for Testing Materials. It is hoped that future editions will still further extend the number of subjects covered.—Arthur Schroder.

Die Dauerfestigkeit der Werkstoffe und der Konstruktionselemente. By Otto Graf. Verlag von Julius Springer, Berlin, 1929. Paper, 7 × 10 inches, 131 pages. Price, 14 R. M.

The book is a review of our knowledge of the permanent strength of material when subjected to repeated and long-continued stresses. It brings together in convenient form the available results of tests by the author and other engineers. The materials discussed include: cast iron, cast steel, copper, nickel, aluminum, magnesium and their alloys, as well as stone, reinforced concrete, wood and glass.—E. Fetz.

Sources of Cadmium

Apparently the only commercial sources of cadmium are zinc minerals, says the United States Bureau of Mines, Department of Commerce, in a recently issued publication. Greenockite, otavite (a basic carbonate), przibramite (a reddish zinc blende containing up to 5 percent of cadmium), and a few other cadmium minerals are, however, recognized. Most zinc ores contain cadmium in minute quantity, and the cadmium of commerce has all come from the following sources: Zinc ores treated by fractional distillation; bag-house fume from lead smelters treating zinciferous ores; and residues from the purification of zinc solutions at electrolytic zinc or lithopone plants.

In Silesia, cadmium is strickly a by-product of zinc smelting. Being concentrated in a brownish smoke which appears at the beginning of the distillation it was formerly caught mainly in the "prolongs." Prolongs, which are essentially second condensers, are not employed in the United States because the small amount of zinc that escapes the adapter or first condenser does not pay for the additional labor involved. Even in Silesia prolongs have been discontinued except at works that make a specialty of zinc dust (blue powder). Usually, however, special arrangements are made for burning the vapor from the retorts and leading the fume to a central chamber.

Blue powder containing 4 and up to 8 percent of cadmium has been the main source of cadmium in Europe. This powder and likewise the cadmium-bearing fumes are mixed with carbon and treated by repeated distillation for the recovery of their zinc and cadmium.

In the United States wet methods are used for the recovery of cadmium from flue dusts as well as from the other residues of zinc, lead or copper production. At some stage in these various processes a purified sulphate (rarely a chloride) solution is obtained which contains essentially zinc and cadmium (and thallium). By one process the cadmium from these solutions is precipitated by zinc dust and this precipitate is redissolved in acid and electrolyzed. Aluminum cathodes are used and the deposited cadmium is periodically stripped, melted and cast into sticks. This general process is in use at several American plants and at the electrolytic zinc plants at Trail, British Columbia and Risdon, Tasmania. According to the other process the cadmium is precipitated from solution in the form of a sponge by means of zinc slabs or plates. This sponge is then distilled and the condensed cadmium is remelted and cast into sticks.

Fumes from brass works have been considered as potential sources of cadmium. Brass made from slab zinc containing as much as 0.5 percent of cadmium has been found to contain scarcely a trace of the cadmium, because that element, being even more volatile than the zinc, is almost wholly volatilized when added to the molten copper. More than 10 years ago the Bureau of Mines estimated that 400 pounds of cadmium was lost daily at Waterbury, Conn., but now purer zinc is being used and the quantity of cadmium that escapes in this way is probably less than formerly. In any event, even when prices of cadmium were two or three times higher than they are now, it was not considered economical to try to recover this metal.

Prof. Bradley Stoughton, professor of metallurgy at Lehigh University, received the Grasselli Medal for 1929, in recognition of his work on light structural alloys. His address, read at that time, "Metals Used in Aircraft Construction," will appear in the January, 1930, issue of Metals & Alloys.

Francis A. J. Fitzgerald, 59 years old, charter member and a former president of the American Electro Chemical Society, died Oct. 27th, at his home in Niagara Falls, Ontario, a victim of pneumonia. He was born in Dublin, Ireland, the son of Dr. Charles Fitzgerald, a famous surgeon. He came to America in 1893. He was a graduate of Massachusetts Institute of Technology and was one of the founders of the Acheson Graphite Company and for many years conducted the Fitzgerald Research Laboratories.

Patent Department

Through an arrangement with Mr. W. M. Corse, Metallurgical Engineer, Washington, D. C., who operates a well-known Patent Information Service, we are able to publish every month a list of important patents in the metallurgical field from the United States, Canada and Europe. The following countries will be included in the European listing: England, Germany, France, Switzerland, Denmark, Norway, Sweden and Italy.

If our readers wish more information about any of the patents listed below they can get it by writing to our Patent Department, and mentioning the fact that they have seen the reference in METALS & ALLOYS. *We will be prepared to mail copies of United States Patents to clients within twenty-four hours of date of issue by special arrangement. Photostatic copies, translations of claims and of full text of foreign patents will be supplied if desired.*

This service is furnished under special arrangement with Mr. Corse's organization at most reasonable rates. Full information can be secured by writing to Patent Department, METALS & ALLOYS, *419 Fourth Avenue, New York.*

United States Patents

Patents issued from October 15 to Nov. 5, 1929, inclusive

Subject of Invention, Patentee Patent No. and Filing Date

Electron-emitting material and method of making the same (W-Mo-Th). W. B. Gero, Bloomfield, N. J., assignor to Westinghouse Lamp Co. No. 1,731,244. June 29, 1926.

Alloy and its manufacture (W-Ta). J. W. Marden, East Orange, N. J., assignor to Westinghouse Lamp Co. No. 1,731,255. Continuation of application filed Mar. 29, 1924, this application filed Oct. 22, 1926.

Tip for cutting torches. G. C. Quelch, Oakmont, Pa., assignor to International Oxygen Co., Newark, N. J. No. 1,731,265. Aug. 23, 1926.

Resistance alloy (Cr-W). M. N. Rich, East Orange, N. J., assignor to Westinghouse Lamp Co. No. 1,731,267. Mar. 1, 1927.

Pliable tungsten and method of producing the same. M. N. Rich, East Orange, N. J., assignor to Westinghouse Lamp Co. No. 1,731,269. Jan. 23, 1925.

Method of heat treating iron. A. F. Meehan, Chattanooga, Tenn., assignor to Meehanite Metal Corp., Chattanooga, Tenn. No. 1,731,346. Continuation of application filed June 11,1928, this application filed July 22, 1929.

Method of refining lead. J. P. Walker, Hammond, Ind. No. 1,731,365 Aug. 25, 1928.

Method of and apparatus for welding tubes. C. N. Mitchell, Cleveland, Ohio. No. 1,731,390. Jan. 7, 1927.

Plant for washing coal and other minerals by means of liquid streams. A. France, Liege, Belgium. No. 1,731,410. August 27, 1926, in Belgium Nov. 20, 1925.

Production of electrolytically-deposited gold in film or leaf form. W. F. Grupe, Rutherford, N. J. No. 1,731,415. Feb. 23, 1927.

Chromium-plating machine. W. S. Eaton, Sag Harbor, N. Y. No. 1,731,456. Oct. 28, 1926.

Arc-welding tool. J. H. Paterson, Westminster, London, England, assignor to Imperial Chemical Industries Ltd., London. No. 1,731,502. Aug. 7, 1928, in Great Britain Sept. 1, 1927.

Recovery of sulphur from iron pyrites. R. F. Bacon, Bronxville, N. Y. No. 1,731,516. Apr. 13, 1927.

Welding machine. H. S. Powell, Utica, N. Y. No. 1,731,541. July 28, 1927.

Process for hardening high-speed steel. W. Stauffer, Zurich, Switzerland, assignor to the Firm, Akt. Ges. der Maschinenfabriken Escher Wyss & Cie., Zurich, Switzerland. No. 1,731,549. Apr. 7, 1928, in Switzerland Apr. 23, 1927.

Process and composition for treating metals. D. M. Tiller and W. W. Ferree, Kansas City, Mo. No. 1,731,641. Aug. 16, 1926.

Rifle. G. A. Harris, Garfield County, Colo. No. 1,731,660. May 19, 1928.

Process of die-casting cast iron. C. Meier, Valparaiso, Ind. No. 1,731,676. June 20, 1925.

Process for the extraction of mercury from its ores and from residues of their roasting. I. Cavalli, Padua, Italy. No. 1,731,699. Sept. 22, 1927, in Italy Sept. 24, 1926.

Flotation screen. H. B. Houston, Detroit, Mich. No. 1,731,779. Apr. 9, 1926.

Method of producing antifriction bushings. C. Q. Payne, New York, N. Y. No. 1,731,790. Feb. 16, 1927.

Apparatus for treating railway and tramway rails. C. J. Grist, Berkswell, England, assignor of four-fifths to C. W. St. J. Rowlandson, London, Eng. No. 1,731,857. Jan. 4, 1928, in Great Britain Jan. 7, 1927.

Apparatus for the treatment of tools and other small steel or steel alloy articles. C. J. Grist, Berkswell, England, assignor of four-fifths to C. W. St. J. Rowlandson, London, Eng. No. 1,731,858. Original Jan. 4, 1928, divided and this application Dec. 5, 1928, in Great Britain Jan. 7, 1927.

Handling device for foundry ladles or the like. W. Hegarty, Brooklyn, N. Y., and G. E. Deiseroth, Montclair, N. J., assignors to General Electric Co. No. 1,731,897. Apr. 12, 1928.

Treatment of ores and metallurgical products. H. G. Heine, Magdeburg, Germany, assignor to Fried. Krupp Grusonwerk Aktiengesellschaft, Magdeburg-Buckau, Germany. No. 1,731,898. Apr. 23, 1927.

Furnace. R. Malvos, Chartres, and Marcellin Crozemarie, Dreux, France No. 1,731,901. Nov. 14, 1924, in France Nov. 11, 1923.

Electric welding apparatus. P. O. Noble, Schenectady, N. Y., assignor to General Electric Co. No. 1,731,934. Continuation of application filed Sept. 19, 1918, this application filed Sept. 11, 1919, renewed March 18, 1929.

Process for producing metals and alloys. T. R. Haglund, Stockholm, Sweden. No. 1,731,976. Oct. 16, 1926, in Sweden Oct. 23, 1925.

Metal pot for typographical machines. L. W. Willis, Brooklyn, N. Y., assignor to Intertype Corp., New York, N. Y. No. 1,732,075. June 25, 1928.

Electric welding machine. F. P. McBerty, Warren, Ohio. No. 1,732,136. Nov. 2, 1927.

Furnace (Regenerative). G. Naismith and D. M. Naismith, Pittsburgh, Pa. No. 1,732,137. Dec. 12, 1927.

Furnace (Ingot heating). G. Naismith and D. M. Naismith, Pittsburgh, Pa. No. 1,732,138. Dec. 19, 1927.

Process of manufacturing nickel flakes for use as admixture in the active material of alkaline accumulators. E. Breuning, Hagen, and Otto Schneider, Frankfort-on-the-Main, Germany, assignors, by mesne assignments to The Electric Storage Battery Co., Philadelphia, Pa. No. 1,732,179. July 9, 1927, in Germany July 27, 1926.

Apparatus for casting spiral corrugated pipe. D. B. Dimick, Birmingham, Ala No. 1,732,183. July 11, 1928.

Molding flask. J. H. Warner, Fremont, Ohio. No. 1,732,199. June 22, 1928.

Air-toughened alloy steel (Mn-Ni-steel). J. H. Hall and J. S. Comerford, High Bridge, N. J., assignors to Taylor-Wharton Iron and Steel Co., High Bridge, N. J. No. 1,732,202. May 16, 1927.

Small-caliber rifle bullet and process of making the same (jacketed lead core). J. M. Olin and Alfons G. Schuricht, Alton, Ill., assignors to Western Cartridge Co., East Alton, Ill. No. 1,732,211. Oct. 14, 1925.

Casting apparatus. F. S. Kochendorfer, River Forest, Ill., assignor to Western Electric Co., Inc. No. 1,732,236. May 13, 1926.

Production of valves (Welded-on faces). T. E. Murray, Jr., Brooklyn, N. Y. No. 1,732,241. April 8, 1927.

Method of hardening steel. S. I. Salzman, Baltimore, Md. No. 1,732,244. Mar. 29, 1928.

Casting apparatus. W. N. Thode, Chicago, assignor to Western Electric Co., Inc., New York, N. Y. No. 1,732,246. May 13, 1926.

Method of soldering of chain and ring-mesh fabrics. E. Thoma, Pforzheim, Germany, assignor to Ernest Gideon Bek, Pforzheim, Germany. No. 1,732,317. Sept. 4, 1924, in Germany Sept. 10, 1923.

Thorium alloy and method of preparing the same (Th-W group). H. S. Cooper. Cleveland, Ohio, assignor to Kemet Laboratories Co., Inc. No. 1,732,326. May 4, 1925.

Alloy and process of heat treatment (Ni-Cu-Si). M. G. Corson, Jackson Heights, N. Y., assignor to Electro Metallurgical Co. No. 1,732,327. Nov. 19, 1926.

Mold for aluminothermic welding of rails. H. Schultz, Berlin-Lankwitz, Germany. No. 1,732,382. Dec. 10, 1928, in Germany Jan. 26, 1928.

Method of and apparatus for electric welding. F. L. Sessions, Lakewood, Ohio, No. 1,732,383. Oct. 15, 1925, renewed Mar. 5, 1929.

Welding collar for rail joints. J. Wattmann, Berlin-Lankwitz, Germany. No. 1,732,390. Dec. 10, 1928, in Germany Jan. 18, 1928.

Torch (Oxy-acetylene or the like). A. J. Fausek and I. F. Fausek, St. Louis, Mo, No. 1,732,401. Nov. 1, 1924.

Apparatus for cooling the mandrels of tube-rolling mills. H. Idel, Duisburg, Germany, assignor to Demag Akt. Ges., Duisburg, Germany. No. 1,732,404. June 16, 1927, in Germany Apr. 12, 1927.

Machine for making spiral-fin tubing. C. W. Owston, Detroit, Mich. No. 1,732,415. June 3, 1927.

Electrode seal for electric furnaces. J. Bruggmann, Neuenhof, near Baden, Switzerland, assignor to Akt. Ges. Brown, Boveri & Cie., Baden, Switzerland. No. 1,732,431. Dec. 6, 1926, in Germany Jan. 2, 1926.

Electrode holder (for welding electrodes). H. Griffiths, Buffalo, N. Y. No. 1,732,441. Dec. 8, 1926.

Casting machine. I. D. Travis, Salt Lake City, Utah. No. 1,732,448. Aug. 13, 1927.

Casting machine. I. D. Travis, Salt Lake City, Utah. No. 1,732,449. June 15, 1928.

Method and apparatus for coating (galvanizing). C. A. Davis, Youngstown, Ohio. No. 1,732,504. Feb. 12, 1925.

Method and article for the manufacture of tubes. A. Laughlin, Jr., Edgeworth, Pa.; M. M. Laughlin and The Union Trust Co. of Pittsburgh, executors of said A. Laughlin, Jr., deceased, assignors to Central Tube Company, Pittsburgh, Pa. No. 1,732,519. Nov. 15, 1923.

Piston and method of making the same (aluminum alloy). Z. Jeffries and R. S. Archer, Cleveland, Ohio, assignors to Aluminum Co. of America, Pittsburgh, Pa. No. 1,732,557. Apr. 21, 1924.

Piston and process of making same (aluminum alloy). G. D. Welty, Cleveland, Ohio, assignor to Aluminum Company of America, Pittsburgh, Pa. No. 1,732,573. August 2, 1924.

Process for improving the strength qualities of steel wire. W. Püngel, Dortmund. Germany, assignor to the Firm, Vereinigte Stahlwerke Akt.-Ges., Düsseldorf, Germany. No. 1,732,615. June 1, 1927, in Germany June 4, 1926.

Apparatus and method for molding pipe. W. Reynolds, Anniston, Ala., assignor to Alabama Pipe Co. No. 1,732,616. Dec. 17, 1927.

Electric-furnace lining. M. Tilley, Cleveland, Ohio, assignor to National Malleable and Steel Castings Co., Cleveland, Ohio. No. 1,732,623. Aug. 18, 1927.

Method of roasting and reducing ores. B. Christiansen, Smedjebacken, Sweden. No. 1,732,672. Jan. 6, 1928, in Norway Jan. 29, 1927.

Aluminum solder. A. J. Line, Edgbaston, England. No. 1,732,727. June 7, 1926, in Great Britain, Sept. 8, 1925.

Process of reducing ores and the like. W. Buddeus, Berlin-Adlershof, Germany. No. 1,732,788. Jan. 14, 1927, in Germany Jan. 20, 1926.

Metal alloy for use in manufacturing electrical contacts (Ag-Cu). H. M. Fredriksen, Seattle, Wash. No. 1,732,839. May 31, 1927.

Roasting-furnace construction. E. Halse, Bethlehem, Pa., assignor to Bethlehem Foundry and Machine.Co. No. 1,732,843. Nov. 28, 1927.

Roasting-furnace construction. E. Halse, Bethlehem, Pa., assignor to Bethlehem Foundry and Machine Co. No. 1,732,844. Jan. 7, 1928.

Ore-floating apparatus and method. H. D. Hunt, Miami, Ariz. No. 1,732,893. Aug. 6, 1927.

Apparatus for welding the tieplates to steel ties. L. Kuhl and Carl Ritz, Berlin-Charlottenburg, Germany, assignors to Siemens-Schuckertwerke G.m.b.H., Berlin-Siemensstadt, Germany. No1,732,900. May 16, 1927, in Germany Apr. 13, 1926.

Method of removing defects from steel billets. R. M. Rooke, Jr., Jersey City, N. J., assignor to Air Reduction Co., Inc., New York, N. Y. No. 1,732,912. June 2, 1928.

Alloy of aluminum, silicon, and iron. B. D. Saklatwalla, Crafton, Pa., assignor to Vanadium Corp of America, Bridgeville, Pa. No. 1,732,915. Feb. 2, 1928.

Heating furnace (heat treating). D. L. Summey, Waterbury, Conn., assignor to Scovill Mfg. Co., Waterbury, Conn. No. 1,732,916. July 28, 1923.

Electric furnace (resistance furnace). D. L. Summey, Waterbury, Conn., assignor to Scovill Mfg. Co., Waterbury, Conn. No. 1,732,917. Original July 28, 1923, divided and this application Mar. 26, 1927.

Filament support and method of making it (chromium-coated tungsten wire). C. J. Smithells, Bushey, England, assignor to General Electric Co. No. 1,733,076. Apr. 25, 1927, in Great Britain May 14, 1926.

Cupola furnace. F. A. Stevenson, New York, N. Y., assignor to Economy Metal Products Corp., New York, N. Y. No. 1,733,138. Feb. 7, 1928.

Cupola furnace. F. A. Stevenson, New York, N. Y., assignor to Economy Metal Products Corp., New York, N. Y. No. 1,733,139. June 29, 1928.

Cupola furnace. F. A. Stevenson, New York, N. Y., assignor to Economy Metal Products Corp., New York, N. Y. No. 1,733,140. Feb. 26, 1929.

Cupola furnace. F. A. Stevenson, New York, N. Y., assignor to Economy Metal Products Corp., New York, N. Y. No. 1,733,141. Original application June 29, 1928, divided and this application Feb. 26, 1929.

Method of making valve casings (by extrusion). L. Jones, Freeport, N. Y., assignor to The Columbus Machine Co., Columbus, Ohio. No. 1,733,226. Apr. 19, 1924.

Method of producing a hard surface on tools and the like (tungsten carbide). F. L. Scott, Houston, Texas, assignor to Hughes Tool Co., Houston, Texas. No. 1,733,241. Aug. 6, 1928.

Method of manufacturing forks with two and more prongs. O. Hermanni, Hagen, Germany. No. 1,733,260. June 9, 1928, in Germany Apr. 9, 1927.

Heating and forging means. P. R. Hoopes, Hartford, Conn., assignor to Elektromatik Forging Machine Corp. No. 1,733,263. Sept. 2, 1927.

Come along for metal-drawing machines. G. E. Barnhart, Pasadena, Calif. No. 1,733,327. Sept. 12, 1927.

Scotch-hearth rabbling mechanism. H. R. MacMichael, El Paso, Texas, assignor to American Smelting and Refining Co., New York, N. Y. No. 1,733,352. June 22, 1927.

Dry Concentrator. J. H. Macartney, San Francisco, Calif., assignor to American Dry Concentrator Co., San Francisco, Calif. No. 1,733,380. July 3, 1928.

Metal-plate-flanging machine. V. C. Norquist, Kansas City, Mo. No. 1,733,385. June 21, 1926.

Mold jacket. E. A. Parker, Springfield, Ohio, assignor to The Springfield Aluminum Plate & Castings Company, Springfield, Ohio. No. 1,733,387. Jan. 11, 1927.

Lining for hot-gas-carrying conduits. M. E. Cushing, Alabama City, Ala. No. 1,733,403. June 18, 1928.

Process and apparatus for electro-plating tubes. F. A. Fahrenwald, Chicago, Ill. No. 1,733,404. Mar. 15, 1926.

Continuous copper-melting furnace. H. S. Lukens and R. P. Heuer, Philadelphia, Pa. No. 1,733,419. Dec. 19, 1925, renewed Aug. 16, 1929.

Method of making piping. G. A. Ferrand, Grenoble, France. No. 1,733,455. Oct. 11, 1927, in France Aug. 3, 1925.

Zinc-reduction apparatus and process. H. Koppers, Essen-Ruhr, Germany, assignor to The Koppers Development Corp., Pittsburgh, Pa. No. 1,733,500. Aug. 31, 1921, renewed Oct. 19, 1927, in Germany Jan. 8, 1917.

Means for producing articles from granular or plastic substances (making molds). K. G. W. Pettersson, Västeras, Sweden, assignor to Aktiebolaget Lindholmen-Motala, Motala Verkstad, Sweden. No. 1,733,513. Dec. 29, 1927, in Sweden May 29, 1926.

Apparatus for refining metals. H. W. York, New York, N. Y., assignor to American Smelting and Refining Co., New York, N. Y. No. 1,733,522. Feb. 9, 1927.

Flotation process. H. R. Wilson, Tooele, Utah. No. 1,733,570. Apr. 3, 1928.

Casting machine. G. W. Bungay, Plainfield, N. J., assignor, by mesne assignments, to The United States Aluminum Co. No. 1,733,576. Sept. 1, 1926.

Centrifugal casting. W. Gillhausen, Dortmund, Germany, assignor, by mesne assignments, to Centrifugal Pipe Corp. No. 1,733,661. May 23, 1927, in Germany May 25, 1926.

Method of heat treatment of steel. S. Makita, Chatsu-Machi, Muroran-Shi, Hokkaido, Japan, assignor to Kabushiki Kaisha Nihon Seikosho, Tokyo, Japan. No. 1,733,669. Apr. 19, 1927, in Japan June 22, 1926.

Cutting torch. J. R. Rose, Edgeworth, Pa. No. 1,733,698. May 3, 1928.

Recovery of vanadium. R. H. Stevens, G. C. Norris and W. N. Watson, Broken Hill, Northern Rhodesia, South Africa, assignors to Rhodesia Broken Hill Development Co., Ltd., Broken Hill, Northern Rhodesia. No. 1,733,700. Sept. 24, 1926, in the Union of South Africa Apr. 7, 1926.

Composite X-ray target (Th-Ta). J. W. Marden and C. T. Ulrey, E. Orange, and L. F. Ehrke, Newark, N. J., assignors to Westinghouse Lamp Co. No. 1,733,744. Jan. 16, 1926.

Refractory metal and its manufacture (ductile tungsten). J. H. Ramage, Bloomfield, N. J., assignor to Westinghouse Lamp Co. No. 1,733,752. Oct. 28, 1922.

Rod for use in arc welding or cutting. J. B. Green, Chicago, Ill. No. 1,733,795. Feb. 10, 1927.

Composite body and method of producing the same (Mo-Th). J. W. Marden and H. C. Rentschler, E. Orange, N. J., assignors to Westinghouse Lamp Co. No. 1,733,813. Aug. 1, 1921.

Automatic control for centrifugal casting machines. G. C. Pfeffer, Florence Township, Burlington Co., N. J., assignor to Walter Wood, Philadelphia, Pa. No. 1,733,820. June 5, 1928.

Furnace (open-hearth). A. Simonet, Minneapolis, Minn. No. 1,733,829. Feb. 14, 1927.

Wire-feeding mechanism for welding machines. C. Steenstrup, Schenectady, N. Y., assignor to General Electric Co. No. 1,733,835. Nov. 23, 1927.

Wire-feeding mechanism for welding machines. C. Steenstrup, Schenectady, N. Y., assignor to General Electric Co. No. 1,733,836. Nov. 23, 1927.

Process for forming electrodes. J. S. Crossley, Moonee Ponds, Victoria, Australia. No. 1,733,866. Nov. 26, 1926, in Australia Dec. 1, 1925.

Method of welding copper-boiler ends. A. H. Trageser and L. Hassinger, New York, N. Y. No. 1,733,922. Nov. 24, 1928.

Process for the treatment of ores for the recovery of titanium. A. W. Gregory, deceased, Greenwich, London, by M. A. Gregory, executrix, Greenwich, London, England. No. 1,734,034. Oct. 16, 1926.

Thickener. W. S. Orr, Massillon, Ohio, assignor to Central Alloy Steel Corporation, Massillon, Ohio. No. 1,734,044. Apr. 5, 1928.

Spiral-finned tubing and method of making same. H. W. Bundy, Detroit, Mich., assignor, by mesne assignments, to Bundy Tubing Company, Detroit, Mich. No. 1,734,111. June 20, 1927.

Molding system. F. E. McCabe, Chagrin Falls, Ohio, assignor to The Grabler Manufacturing Company, Cleveland, Ohio. No. 1,734,174. Sept. 19, 1925.

Mold carrier. F. E. McCabe, Chagrin Falls, Ohio, assignor to The Grabler Manufacturing Company, Cleveland, Ohio. No. 1,734,175. Sept. 19, 1925.

Mold-shake-out apparatus. F. E. McCabe, Chagrin Falls, Ohio, assignor to The Grabler Manufacturing Company, Cleveland, Ohio. No. 1,734,176. Sept. 19, 1925.

Mold-making machine. F. E. McCabe, Cleveland, Ohio, assignor to The Grabler Manufacturing Company, Cleveland, Ohio. No. 1,734,177. Apr. 29, 1927.

Mold flask. F. E. McCabe, Cleveland, Ohio, assignor to The Grabler Manufacturing Company, Cleveland, Ohio. No. 1,734,300. Sept. 19, 1925.

Cyanide process of treating ores containing precious metals. P. C. Schraps, Guayaquil, Ecuador. No. 1,734,306. Jan. 16, 1925.

Casting apparatus. N. W. D. von Malmborg, Kokomo, Indiana. No. 1,734,313. May 26, 1928.

Casting machine. H. Wetzler, Offenbach-on-the-Main, Germany. No. 1,734,316. April 7, 1928.

Electric furnace. V. Sorrel and L. A. Lafont, Grenoble, France, assignors to Ugine-Infra, Grenoble, France. No. 1,734,536. Aug. 4, 1928.

Inhibitor. L. J. Christmann, Jersey City, N. J., assignor to American Cyanamid Company, New York, N. Y. No. 1,734,560. Sept. 18, 1929.

Inhibiting compound. L. J. Christmann, Jersey City, N. J., assignor to American Cyanamid Company, N. Y. No. 1,734,561. Sept. 18, 1929.

Cutting and welding torch. R. D. McIntosh, River Forest, Ill., assignor to The Imperial Brass Manufacturing Company, Chicago, Ill. No. 1,734,589. Nov. 13, 1924.

Bonded refractory. J. D. Morgan, Maplewood, N. J., assignor to Doherty Research Company, New York, N. Y. No. 1,734,595. Feb. 17, 1927.

Pot furnace. L. C. Koenig, Cudahy, Wis., assignor to Hevi Duty Electric Company, Milwaukee, Wis. No. 1,734,629. Apr. 24, 1928.

Method of and apparatus for annealing. O. Tangring, Worcester, Mass., assignor to The American Steel and Wire Company of New Jersey. No. 1,734,697. Apr. 2, 1927.

Cleaning metal surface. H. Adler, Chicago Heights, Ill., assignor to Diversey Manufacturing Company. No. 1,734,706. Mar. 29, 1926.

Refractory product and process for making the same. I. Harter, Dongan Hills, N. Y., and A. M. Kohler, Jersey City, N. J. No. 1,734,726. May 25, 1923.

Mixing apparatus. G. A. Seeley, Irvington, N. J., assignor to Western Electric Company, Incorporated, New York, N. Y. No. 1,734,747. July 24, 1928.

Conveyer for a continuous normalizing furnace. S. J. Leskawa, Youngstown, Ohio. No. 1,734,814. Jan. 4, 1927.

Pyrometer. C. B. Thwing, Philadelphia, Pa., assignor to Thwing Instrument Company, Philadelphia, Pa. No. 1,734,837. Sept. 3, 1925.

Radiant-heat oven. A. W. Morse, Long Island City, N. Y. No. 1,734,870. Aug. 5, 1926.

Heat-treating oven. A. W. Morse, Long Island City, N. Y. No. 1,734,871, Sept. 2, 1926.

Electroplating tank. C. E. Jones, Schenectady, N. Y., assignor to General Electric Company, a Corporation of New York. No. 1,734,909. Oct. 15, 1925.

Treatment of malleable castings. I. R. Valentine, Erie, Pa., assignor to General Electric Company, a Corporation of New York. No. 1,734,928. May 20, 1926.

Temperature-stabilized shaft for turbines and method of making the same. S. H. Weaver, Schenectady, N. Y., assignor to General Electric Co., a Corporation of New York. No. 1,734,930. Dec. 22, 1927.

Apparatus for casting metals. J. Züblin, Singen on the Hohentwiel, Baden, Germany. No. 1,734,786. Oct. 10, 1927.

Method and apparatus for electrically heating articles. H. E. Norman, Springfield, Mass., assignor to National Equipment Company, Springfield, Mass. No. 1,734,913. July 14, 1927.

Weld rod and method of making the same. J. M. Weed, Ballston Lake, N. Y., assignor to General Electric Company. No. 1,734,932. Oct. 27, 1927.

Preservation of metallic surfaces. J. C. Vignos, Nitro, W. Va., assignor to The Rubber Service Laboratories Co., Akron, Ohio. No. 1,734,949. Mar. 8, 1928.

Means of preserving metallic surfaces. J. C. Vignos, Nitro, W. Va., assignor to The Rubber Service Laboratories Co., Akron, Ohio. No. 1,734,950. Apr. 18, 1928.

Permanent Metal Foundry Mold. E. C. Lewis, Teddington, England, assignor to The Automotive Engineering Co., Ltd., Twickenham, England. No. 1,734,974. Sept. 7, 1928.

Coupling box for rolling mills. P. G. Palmgren, Gottenborg, Sweden, assignor to Aktiebolaget Svenska Kullagerfabriken, Gottenborg, Sweden. No. 1,734,978. Dec. 31, 1927.

Pickling apparatus. S. L. Williams, Bridgeport, Ohio, assignor to Extruded Metal Products Co., Bridgeport, Ohio. No. 1,734,986. Mar. 22, 1929.

Method of filtering and thickening mixtures. G. Cruickshank. Trail, British Columbia, Canada, assignor, by mesne assignments, to Genter Thickener Company. No. 1,734,999. Oct. 10, 1925.

Copper coating. J. G. Dely, New York, N. Y., assignor to Chemical Research & Designing Corp., N. Y. No. 1,735,000. Apr. 19, 1928.

Casting apparatus for laminated rotors. N. Lester, Worcester, Mass., assignor to P & R Tool Co., Inc., Worcester, Mass. No. 1,735,049. Sept 17, 1928.

Art of making steel. F. W. Davis, Milford, Del., assignor to S. G. Allen, trustee. No. 1,735,074. June 2, 1924.

Mold coating. H. S. Lee, Plymouth, Mich. No. 1,735,120. Mar. 8, 1926.

Universal torch machine. E. L. Ragonnet, New York, N. Y., assignor to Air Reduction Co., Inc., New York. No. 1,735,129. May 9, 1928.

Flotation process. S. P. Warren, Golden, Colo. No. 1,735,190. Apr. 19, 1928.

Method of butt-welded tubes. D. W. Chisholm, Glasgow, Scotland, assignor to the Birchfield Engineering Co., Ltd., Cardiff, Wales. No. 1,735,234. Apr. 29, 1926.

Furnace-port construction. L. N. McDonald, Youngstown, Ohio. No. 1,735,256. Oct. 27, 1921.

Process of coating metallic aluminum or aluminum alloys with aluminum oxide skin. T. Kujirai, Nakano-Machi, Toyotama-Gori, and S. Ueki, Oju-Machi, Kitatoshima-Gori, Tokyo, Japan, assignors to Zaidan Hojin Rikafaku Kenkyujo, Hongo-Ku, Tokyo. No. 1,735,286. Dec. 2, 1924.

Method of attaching fins to cylinders. L. J. Purdy, Syracuse, N. Y., assignor, by mesne assignments, to Franklin Development Corp., Syracuse, N. Y. No. 1,735,213. Jan. 4, 1928.

Bar twister for rolling mills. A. T. Blocker, Chicago, Ill., assignor to Interstate Iron and Steel Company, Chicago, Ill. No. 1,735,282. June 22, 1927.

Blast furnace. Y. Murakami, Oaza, Hiratsuka-Mura, Ebara-Gori, Tokyo, Japan. No. 1,735,293. Sept. 14, 1926.

Bearing for rolling mills and the like. D. Jones, Gorphwipfa, Tiresed, Glanamman, Wales. No. 1,735,319. Jan. 28; 1928.

Conveyor soldering machine. N. F. Paradise, Shanghai, China, assignor to Standard Oil Company of New York, New York. No. 1,735,336. Nov. 19, 1926.

Pure iron of small grain size. W. Meiser, Ludwigshafen-on-the-Rhine, W. Schuchardt, Mannheim, and O. Kramer, Oppau, Germany, assignors to I. G. Farbenindustrie Aktiengesellschaft, Frankfort-on-the-Main, Germany. No. 1,735,405. Aug. 28, 1928.

Electric furnace. F. W. Brooke, Pittsburgh, Pa., assignor to William Swindell & Brothers, Pittsburgh, Pa. No. 1,735,419. June 2, 1928.

Process for forming an electrically insulating and anticorrosive oxide coating on aluminum material. S. Setoh, Tokyo, and S. Ueki, deceased, Oaza, Japan, Uno Ueki, Oaza, Japan, administratrix, assignors to Zaidan Hojin Rikagaku Kenkyujo, Tokyo, Japan. No. 1,735,509. Oct. 22, 1926.

Apparatus for coating bearings or the like. C. W. Eggenweiler and W. J. Fiegel, Detroit, Mich., assignors to Bohn Aluminum and Brass Corporation, Detroit, Mich. No. 1,735,534. Apr. 26, 1926.

Tin-plate package. H. D. Scott, Wheeling, W. Va. No. 1,735,548. June 26, 1928.

Method of securing metal end couplings on tubular members. C. L. Deckard, Kansas City, Mo. No. 1,735,563. May 25, 1928.

Heating furnace. W. H. Fitch, Allentown, Pa. No. 1,735,605. Dec. 18, 1926.

Heating furnace. W. H. Fitch, Allentown, Pa. No. 1,735,606. Dec. 18, 1926.

Heating furnace. W. H. Fitch, Allentown, Pa. No. 1,735,607. Dec. 18, 1926.

Heating furnace. W. H. Fitch, Allentown, Pa. No. 1,735,608. Dec. 18, 1926.

Method of making endless wire fabrics. R. Franck, Selestat, France. No. 1,735,640. Dec. 30, 1927.

Regenerative furnace. F. E. Kling, Youngstown, Ohio. No. 1,735,687. Feb. 28, 1922.

Steel alloy. A. Fry, Essen-on-the-Ruhr, Germany, assignor to F. Krupp Aktiengesellschaft, Essen-on-the-Ruhr, Germany. No. 1,735,744. July 28, 1927.

Rolling mill. H. R. Geer, Johnstown, Pa., assignor to Bethlehem Steel Company. No. 1,735,746. Jan. 13, 1926.

Drive for roller tables in rolling mills. A. T. Keller, Bethlehem, R. H. Stevens, Johnstown, Pa., assignors to Bethlehem Steel Co. No. 1,735,767. Mar. 31, 1927.

Process of producing watch parts. R. Straumann, Waldenburg, Switzerland, assignor to the Firm Thommens Uhrenfabriken A. G., Waldenburg, Switzerland. No. 1,735,805. Sept. 20, 1928.

United States Reissue Patents

Subject of Invention, Patentee, Patent No., and Filing Date

Rustproofing process. W. H. Allen, Detroit, Mich., assignor, by mesne assignments, to Parker Rust Proof Company, Detroit, Mich. No. 17,484. Nov. 9, 1928.

Austrian Patents

Subject of Invention, Patentee, and Patent No.

Patents whose term began on May 15, 1929

Elastic pulling ring for wire-drawing machines. Drahtindustrie Peter Darmstadt & Co., G.m.b.H., Frankfurt a.M. No. 114,831.

Electric furnace for bulk materials. Akt.-Ges. Brown, Boveri & Cie., Baden, Switzerland. No. 114,855.

Continuously-operating reverberatory furnace. "Ilva" Alti Forni e Acciairie d'-Italia, Genoa, Italy. No. 114,856.

Method of and device for cooling burners, abutments, slag pockets and other parts exposed to high temperatures, particularly those of metallurgical furnaces, especially open-hearth furnaces. Oesterreichische Alpine Montangesellschaft, Vienna, Austria. No. 114,860.

Process for making bridged-over cavities in sand molds for bearings. Metallbank und Metallurgische Gesellschaft, Frankfurt a.M., Germany. No. 114,-895.

Device for casting metals. J. Züblin, Singen am Hohentwill, Germany. No. 114,892.

Process for recovering nickel from compound sheets composed of layers of copper and nickel. E. Breuning, Hagen, Westfalen, Germany. No. 114,846.

Radiation pyrometer. Hartmann & Braun Akt.-Ges., Frankfurt a.M., Germany. No. 114,813.

Process for the electrolytic production of metallic coatings. Siemens & Halske Akt.-Ges., Berlin, Germany and Vienna, Austria. No. 114,843.

Process for coating metallic radiant bodies of electric radiation devices with refractory metals or metallic compounds. E. Harsanyi, Budapest, Hungary. No. 114,859.

Process for the surface treatment of aluminum and aluminum alloys. A. Pacz, Cleveland, Ohio. No. 114,839.

Process for pickling objects of iron or its alloys. Werk Rothau der Eisenwerk Akt.-Ges. Rothau-Neudek, and F. Eisenkoll, Rothau, Czechoslovakia. No. 114,841.

Process for coating objects with aluminum and aluminum alloys. The Expanded Metal Co., Ltd., London, England. No. 114,842.

Process for protecting metallic objects against corrosion by stray currents. E. Cumberland, Kingston Hill, Surrey, England. No. 114,845.

Apparatus for cleaning and degreasing metallic objects. Dr. Alexander Wacker Ges. für Electrochemische Industrie G.m.b.H., Munich, Germany. No. 114,847.

Preparation for the preliminary treatment of metals before application of coatings. J. H. Gravell, Ambler, Pa. No. 114,848.

Atomizer for pulverulent materials. F. Schori, Oerlikon, Switzerland. No. 114,853.

Arc-welding electrode and method of making the same. F. Dworzak, Vienna, Austria. No. 114,854.

Process for producing regions of adherence for electrolytic deposits on light metal objects. Leipziger Schnellpressenfabrik Akt.-Ges. vormals Schmiers Werner & Stein, Leipzig, Germany. No. 114,863.

Electric forging press. A. Friederici, Köln-Mülheim Germany. No. 114,799.

Automatic arc-welding apparatus. Siemens-Schuckertwerke G.m.b.H., Berlin-Siemensstadt, Germany. No. 114,806.

Method of and burner for autogenous perforating and cutting. Drägerwerk Heinr. & Bernh. Dräger, Lübeck, Germany. No. 114,807.

Device for accurately adjusting the cutting or welding burner of cutting or welding machines. Akt.-Ges. für Tiefbohrtechnik und Maschinenbau vormals Trauzl & Co., Vienna, Austria, and F. Müller, Vienna, Austria. No. 114,-824.

Process for making metal ware, especially spoons and the like, from strip material. K. Thiel, Vienna, Austria. No. 114,823.

British Patents

(Specifications open to Public Inspection in Great Britain)

Subject of Invention, Patentee, Patent No., and Filing Date

Manufacture of cast-iron grinding balls. F. Krupp Grusonwerk Akt.-Ges. No. 319,350. Sept. 22, 1928.

Constructional steel. F. Krupp Akt.-Ges. No. 319,319. Sept. 20, 1928.

Process of casting light metals, more particularly magnesium and alloys thereof in sand moulds. I. G. Farbenindustrie Akt.-Ges. No. 319,272. Sept. 19, 1928.

Method for dressing residues containing metal. Hirsch Kupfer-und Messingwerke Akt.-Ges. No. 319,327. Sept. 20, 1928.

Moulding-sand projecting-machines. W. Seidemann. No. 319,278. Sept. 19, 1928.

Rotary-tube furnaces. Metallges. Akt.-Ges. No. 319,335. Sept. 20, 1928.

Froth-flotation methods. Aluminium, Ltd. No. 319,685. Sept. 26, 1928.

Process for improving the quality of forged mild steel or welded iron chains. Vereinigte Stahlwerke Akt.-Ges. No. 319,772. Sept. 28, 1928.

Metallic mixtures, and methods of obtaining the same. R. W. Hyde. No. 319,-775. Sept. 29, 1928.

Casting processes and moulds therefor. J. Durand. No. 319,777. Sept. 29, 1928.

Methods of making carbides. British Thomson-Houston Co., Ltd. No. 319,-698. Sept. 26, 1928.

British Patents

(Complete Specifications Accepted)

Subject of Invention, Patentee, Patent No., and Filing Date

Recovery of manganese values from solutions containing manganese. S. G. S Dicker (Bradley-Fitch Co.). No. 319,392. June 19, 1928.

Method of producing molybdenum-bearing iron. Climax Molybdenum Co. No. 299,800. Nov. 1, 1927.

Casting iron alloys. Climax Molybdenum Co. No. 308,751. Mar. 28, 1928.

Furnaces or plant for the heating and heat-treatment of metals or other materials or goods. Summers & Sons, Ltd., J. and C. Bottomley. No. 319,300. June 20, 1928.

Machinery for use in connection with the manufacture of tinplates or sheets and other like plates or sheets. H. S. Thomas and W. R. Davies. No. 319,-414. June 26, 1928.

Method and apparatus for continuously producing metal sponge. H. G. Flodin. No. 293,868. July 14, 1927.

Manufacture of iron and steel tubes. F. Sonnichsen, F. A. Frisch, and H. A. Nicolaysen. No. 319,471. Aug. 25, 1928.

Electrodes for electric arc welding or soldering. Alloy Welding Processes, Ltd., and E. J. Clarke. No. 319,487. Sept. 20, 1928.

Carrying-devices or conveyors for the collecting-grids of cooling beds in rolling-mills. F. Krupp Grusonwerk Akt.-Ges. No. 304,683. Jan. 24, 1928.

Light-metal rivets. Vereinigte Aluminium-Werke Akt.-Ges. No. 303,126. Dec. 28, 1927.

Core-boxes for use in steel-melting furnace holes. F. H. Balfour and J. W. B. Wood. No. 319,568. Feb. 1, 1929.

Treatment of materials for the concentration of iron contained therein. S. G. S. Dicker (Bradley-Fitch Co.). No. 319,309. June 19, 1928.

Direct production of iron or steel. H. D. Pierson, J. J. A. G. Sanberg, and I. C. J. Van Dusseldorp (trading as Heldring & Pierson), A. E. M. Ledeboer; J. L. Van Houten, M. Willemsteyn, Jagt, B. G. H. Van Der, A. J. A. I. De Schepper, J. G. H. I. De Schepper, T. B. G. Moliere, H. Kempkers, J. C. Hoos, J. F. Colinet; J. Ellerman; R. A. A. R. Von Skene, K. H. H. Van Bennekom, Dr. E. C. P. Gallas, Naamlooze Vennootschap C. Swarttouw's Stuwadoors Maatschappij, and S. W. B. Hyde (trading as Staal-Syndicaat Dr. Ledeboer). No. 287,925. March 30, 1927.

Machines for trimming metal blanks. R. L. Wilcox and Waterbury Farrel Foundry and Machine Co. No. 319,799. March 27, 1928.

Electric furnaces. V. Stobie. No. 319,802. March 31, 1928.

Case-hardening metals. P. W. Shimer and E. B. Shimer. No. 292,557. June 22, 1927.

Briquettes for use in refining or treating molten metal. G. C. Castle, C. Wood and Beecroft & Partners, Ltd. No. 319,603. June 22, 1928.

Annealing-cases. Aciéries Réunies De Burbacheich-Dudlelange Soc. Anon. No. 310,489. April 27, 1928.

Electrical resisting bodies. Carborundum Co., Ltd., (Carborundum Co.). No. 319,647. June 25, 1928.

Process for the treatment of zinc ores. Soc. Miniere et Metallurgique de Penarroya. No. 313,430. June 11, 1928.

Manufacture and production of magnetic cores of high permeability. J. Y. Johnson (I. G. Farbenindustrie Akt.-Ges.). No. 319,854. July 14, 1928.

Production of iron or steel of a low degree of cold-brittleness and blue fracture and other desirable characteristics. Vereinigte Stahlwerke Akt.-Ges. No. 294,246. July 21, 1927.

Process for working-up materials containing lead, tin, copper and antimony. Hüttenwerk Niederschöne-Weide Akt.-Ges. No. 294,487. July 21, 1927.

Methods and apparatus for froth-flotation processes. F. Krupp Grusonwerk Akt.-Ges. No. 310,834. May 1, 1928.

Shaft furnaces and reaction chambers for treating solid materials and gases. Aktieselskabet Norsk Staal (Elektrish-Gas-Reduktion), and E. Edwin. No. 295,999. August 22, 1927.

Process for the manufacture of metallic substances with a fibrous structure. Kaiser-Wilhelm-Institut für Eisenforschung. No. 296,986. Sept. 10, 1927.

Machines for grinding ores, minerals, stones, and the like. J. R. Broadley. No. 319,897. Aug. 29, 1928.

Alloys. W. P. Digby. No. 319,899. Aug. 30, 1927.

Manufacture of hollow metal bars. R. A. Bedford and J. Kendrick. No. 319,934. Sept. 28, 1928.

Magnetic separating-machines. H. H. Thompson and A. E. Davies. No. 319,943. Oct. 11, 1928.

Production of an aluminum alloy. D. R. Tullis. No. 319,967. Oct. 31, 1928.

Process of making shaped pieces consisting of homogeneous alloys of lead with alkali metals or alkaline earth metals. O. Y. Imray (I. G. Farbenindustrie Akt.-Ges.). No. 300,129. Nov. 5, 1928.

Process of producing cast drills for wood. E. Schleicher. No. 320,013. March 21, 1929.

Treatment of ores and the like containing manganese. S. G. S. Dicker (Bradley-Fitch Co.). No. 319,605. June 19, 1928.

Manufacture and production of magnetic cores of high permeability. J. Y Johnson (I. G. Farbenindustrie Akt.-Ges.). No. 320,016. July 14, 1928.

Apparatus for water-cooling drawn wire. E. W. T. Rees. No. 320,152. July 18, 1928.

Manufacture and production of metals. J. Y. Johnson (I. G. Farbenindustrie Akt.-Ges.). No. 320,177. Aug. 13, 1928.

Recovery of precious metals by amalgamation. D. Enzlin and J. A. Eklund. No. 320,185. Aug. 20, 1928.

Electric resistance furnace for the thermal treatment of metals and other substances. Infra. No. 297,826. Sept. 29, 1927.

Live rollers, such as those used in rolling mills. F. Krupp Grusonwerk Akt.-Ges. No. 306,120. Feb. 17, 1928.

Continuous soldering. M. Orenstein. No. 306,081. Feb. 15, 1928.

Ferrous alloys. S. E. Dawson. No. 320,332. April 4, 1928.

Manufacture of metal billets, blooms, ingots, or the like and the production of hollow bars therefrom. F. F. Gordon. No. 320,316. April 5, 1928.

Hard metal compositions, and methods of making the same. British Thomson-Houston Co., Ltd. No. 288,521. April 6, 1927.

Hollow metal air-screw propeller blades. Vickers, Ltd., and R. K. Pierson. No. 320,365. May 7, 1928.

Apparatus for electrolytically depositing chromium. Soc. Chimique de la Seine, and V. Szidon. No. 320,440. July 28, 1928.

Furnace for the sintering, burning, and roasting of substances. E. C. Loesche. No. 298,651. Oct. 14, 1927.

Manufacture of structures comprising metal bars or like members welded together at their ends or intersections. W. R. Hume. No. 320,538. Oct. 29, 1928.

Protecting carbon electrodes from consumption in the atmosphere. I. G. Farbenindustrie Akt.-Ges. No. 302,891. Dec. 23, 1927.

Process of employing cerium in the production of steel and iron. I. G. Farbenindustrie Akt.-Ges. No. 302,574. Dec. 17, 1927.

Manufacture of cast steel objects such as locomotive wheels or the like. N. Leonard. No. 302,364. Dec. 15, 1927.

Casting and rolling copper. United States Metals Refining Co. No. 305,998. Feb. 13, 1928.

Electrodes for electric arc welding or soldering. Alloy Welding Processes, Ltd. No. 307,760. March 12, 1928.

Electrodes for electric arc welding or soldering. Alloy Welding Processes, Ltd. No. 320,596. March 13, 1929.

Method of casting ingots. E. C. Washburn. No. 320,600. May 15, 1928.

Apparatus for severing moving articles. Steel & Tubes, Inc. No. 310,015. April 21, 1928.

Polishing-preparation for metal and other surfaces, and process for manufacturing said material. A. Van Der Bruggen. No. 309,853. April 16, 1928.

Process and apparatus for rolling seamless pipes. R. Urban. No. 320,702. Aug. 1, 1928.

Testing-instruments for measuring the mechanical properties of steel and other materials. L. H. Hounsfield. No. 320,704. Aug. 4, 1928.

Flanged tubes. Bromford Tube Co., Ltd., J. Rist, and T. D. Norris. No. 320,754. Oct. 9, 1928.

Centrifugally-cast pipes. W. H. Millspaugh. No. 320,781. Nov. 1, 1928.

Apparatus for galvanizing or coating metallic sheets. D. Jones. No. 320,811. Dec. 13, 1928.

Separation of materials of different physical qualities especially of raw mining products. F. Krupp Grusonwerk Akt.-Ges. No. 302,725. Dec. 21, 1927.

Electrolytic preparation or purification of metals. L. St. C. Broughall. No. 320,818. Dec. 31, 1928.

Tube joints. Mannesmannrohren Werke. No. 320,828. Dec. 6, 1928.

Driving-devices for "pilgrim step" motion rolling trains. Siemens-Schuckertwerke Akt.-Ges. No. 304,734. Jan. 25, 1928.

Electrolytic manufacture of iron. E. Kelsen. No. 306,151. Feb. 16, 1928.

Method of soldering iron and steel parts. F. Von Wurstemberger. No. 309,-032. April 3, 1928.

British Patents

(Amended Specifications Published)

Subject of Invention, Patentee, Patent No.

Alloys. Johnson (I. G. Farbenindustrie Akt.-Ges.). No. 291,522.

Extraction of tin. Wilder & ors. No. 294,703.

Canadian Patents

Subject of Invention, Patentee, Patent No., and Filing Date

Electrolytic extraction of pure aluminum. J. Weber and A. von Zeerleder, Neuhausen, Switzerland, and W. D. Treadwell, Zurich, Switzerland. No. 293,660. Nov. 16, 1927.

Apparatus for preparing casting molds. B. L. M. van der Lande and G. Komen, Deventer, Netherlands. No. 293,671. Mar. 26, 1928.

Process for making briquettes. H. Apfelbeck, Falkenau o/Eger, Czechoslovakia. No. 293,672. Apr. 5, 1929.

Manufacture of zinc. H. E. Coley, London, England. No. 293,690. Jan. 20, 1928.

Process for the production of tin. W. Witter, Halle, Saale, Germany. No 293,729. May 2, 1928.

Method of producing metals from oxide ores. E. G. T. Gustafsson, Stockholm, Sweden. No. 293,745. Apr. 1, 1927.

Process for producing metals in electric furnaces. E. G. T. Gustafsson, Stockholm, Sweden. No. 293,746. May 11, 1927.

Mold. The Aluminium Ltd., Toronto, Ont., assignee of The Aluminum Company of America, Pittsburgh, Pa., assignee of M. Guyot, Cleveland, Ohio. No. 293,766. Jan. 21, 1928.

Mold. The Aluminium Ltd., Toronto, Ont., assignee of The Aluminum Company of America, Pittsburgh, Pa., assignee of A. B. Norton, Cleveland, Ohio. No. 293,767. Jan. 21, 1928.

Apparatus for reclaiming metals. The Aluminium Ltd., Toronto, Ont., assignee of The Aluminum Company of America, Pittsburgh, Pa., assignee of T. D. Stay and C. O. Tessier, Cleveland, Ohio. No. 293,768. Feb. 4, 1928.

Tubing. The Bundy Tubing Co., assignee of W. W. Anderson and A. Gardner, assignee of H. W. Bundy, all of Detroit, Mich. No. 293,780. Nov. 3, 1928.

Leading-in wire (iron-nickel). The Canadian Westinghouse Co., Ltd., Hamilton, Ont., assignee of W. C. Sproesser, East Orange, N. J. No. 293,781. Sept. 28, 1928.

Apparatus for producing magnesium by fusion electrolysis. I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany, assignee of G. Pistor, Leipzig, and R. Suchy, K. Staub and W. Moschell, Bitterfeld, Germany. No. 293,796. Nov. 21, 1928.

Anti-rust paint. I. G. Farbenindustrie Akt.-Ges., assignee of H. Schladebach, Dessau in Anhalt and H. Hahle, Dessau-Ziebigk, Anhalt, Germany. No. 293,807. Feb. 15, 1929.

Electric furnace terminal. The Harper Electric Furnace Corp., Philadelphia, Pa., assignee of F. A. J. Fitzgerald, Niagara Falls, N. Y., and J. Kelleher, Chippewa, Ont. No. 293,820. Mar. 5, 1928.

Electric furnace terminal. The Harper Electric Furnace Corp., Philadelphia, Pa., assignee of F. A. J. Fitzgerald, Niagara Falls, N. Y., and J. Kelleher, Chippewa, Ont. No. 293,821. Jan. 1, 1929.

Method of refining antimony. Norddeutsche Affinerie, Hamburg, assignee of H. Roscher, Hamburg, Germany. No. 293,842. Oct. 11, 1927.

Manufacture of metallic powders. La Société Anonyme Trefileries et Laminoirs du Havre, Anciens Établissements Lazare Weiller, Société Coopérative de Rugles et Canalisation électriques réunis, assignee of E. Drouilly, both of Paris, France. No. 293,855. Nov. 3, 1928.

Method of treating metals. The Western Electric Co., Inc., New York, N. Y., assignee of C. D. Anderson, Oak Park, Ill. No. 293,871. Jan. 6, 1928.

Method of producing dense iron and iron alloys directly out of oxide ores. H. G. E. Cornelius, Stockholm, assignee of H. G. Flodin, Roslags-Näsby, and E. G. T. Gustafsson, Stockholm, Sweden. No. 293,889. June 25, 1925.

Electric furnace. E. Bornand and H. A. Schlaepfer, Geneva, Switzerland. No. 293,895. Nov. 23, 1928.

Electric furnace. C. J. Hayes, Providence, R. I. No. 293,930. Aug. 24, 1928.

Process for cleaning iron and steel electrochemically. Q. Marino, Paris, France, No. 293,938. Oct. 15, 1929.

Concentrating table. D. F. Stedman, Vancouver, B. C. No. 293,950. Aug. 28, 1928.

Production of iron and steel. H. J. van Royen, Horde, Westfalen, Germany. No. 293,953. July 16, 1928.

Method of casting metallic objects. The Madsenell Corp., assignee of C. P. Madsen, both of New York, N. Y. No. 294,032. May 23, 1924.

Chromium plating process. The Metals Protection Corp., assignee of H. C. Peirce, both of Indianapolis, Ind. No. 294,034. Oct. 22, 1926.

Chromium plating process. The Metals Protection Corp., assignee of J. C. Patten, both of Indianapolis, Ind. No. 294,035. Oct. 3, 1927.

Method of casting iron pipes. The National Iron Corporation Ltd., Toronto, Ont., assignee of J. B. Ladd, Philadelphia, Pa. No. 294,036. May 9, 1924.

High-frequency furnace. The Westinghouse Lamp Co., Bloomfield, N. J., assignee of H. C. Rentschler and J. W. Marden, East Orange, N. J. No. 294, 056. July 15, 1925.

Production of ternary alloy bearing metals (Cu-Sb-Pb). E. Abel, Vienna, Austria. No. 294,071. June 25, 1928.

Method of separating undesired constituents from alloys. P. Kemp, Vienna, Austria. No. 294,097. June 25, 1928.

Manufacture of rails. S. B. Sheldon, Duluth, Minn. No. 294,119. May 21, 1928.

Ore mill. The American Manganese Steel Co., Chicago, Ill., assignee of D. H. Young, Berkeley, Calif. No. 294,129. July 30, 1928.

Apparatus for producing zinc dust. The American Smelting and Refining Co., New York, N. Y., assignee of F. P. Lannon, Jr., Sands Springs, Okla. No. 294,133. May 25, 1928.

Separation of metals (carbonyl forming metals). I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., assignee of C. Muller, Mannheim, and L. Schlecht and E. Keunecke, Ludwigshafen a.Rh., Germany. No. 294,151. Feb. 16, 1928.

Method of reducing zinciferous materials. The New Jersey Zinc Co., New York, N. Y., assignee of F. G. Breyer and E. H. Bunce, Palmerton, Pa. No. 294,166. July 27, 1927.

Casting machine. The Wheeling Stamping Co., assignee of W. T. Davis and J. A. McGinnis, all of Wheeling, W. Va. No. 294,183. June 1, 1927.

French Patents

Subject of Invention, Patentee, Patent No., and Filing Date

Steel. Vereinigte Stahlwerke Akt.-Ges. No. 671,124. Mar. 8, 1929.

Device for intermittent or alternate blowing, applicable especially to blast furnaces and similar apparatus. J. Hickman and E. Emparan. No. 671,223. Mar. 11, 1929.

Method of supplying air to multi-stage roasting furnaces. T. Lang. No. 671,-277. Mar. 11, 1929.

Process for the recovery of metals. I. G. Farbenindustrie Akt.-Ges. No. 671,-320. Mar. 12, 1929.

Tubular furnace for carrying out exothermic reactions or combined exothermic and endothermic reactions. T. Lang. No. 671,343. Mar. 12, 1929.

Rolling mill for rolling wheel disks. O. Tenschert. No. 671,365. Mar. 12, 1929.

Process for hardening structural steels containing copper. Vereinigte Stahlwerke Akt.-Ges. No. 671,416. Mar. 13, 1929.

Process for making circular metal disks having a circular central hole. R. Kronenberg. No. 671,089. Mar. 8, 1929.

Process for welding iron and its alloys, in particular, with the electric arc. Fried. Krupp. Akt.-Ges. No. 671,117. Mar. 8, 1929.

Thermic mixture. Metal and Thermit Corp. No. 671,176. Mar. 9, 1929.

Improvements to machines for ramming molds. Landon Radiator Co., Inc. No. 671,187. Mar. 9, 1929.

Chemical process for blackening iron and steel. L. Taricco. No. 671,226. Mar. 11, 1929.

Welding magnesium alloys. I. G. Farbenindustrie Akt.-Ges. No. 671,501. Mar. 15, 1929.

Improvements to electric furnaces. B. H. Stone. No. 671,262. Mar. 8, 1929.

Process for increasing the conductivity of the atmosphere around electric arcs, hot gases and the like. I. G. Farbenindustrie Akt.-Ges. No. 671,323. Mar. 12, 1929.

Process for making baths giving very dense and adherent metallic deposits. M. Schlotter. No. 671,386. Mar. 13, 1929.

Process for utilizing slag in the manufacture of cast iron and steel. A. L. M. Gillot. No. 671,554. Mar. 16, 1929.

Process and apparatus for annealing strip metal. Electric Furnace Co., Ltd. No. 671,585. Mar. 16, 1929.

Means for cooling the roofs of open-hearth and similar furnaces. Witkowitzer Bergbau-und-Eisenhütten-Gerwerkschaft, and A. Rotter. No. 671,701. Mar. 19, 1929.

Aluminum alloy. Société Fontaine & Cie. No. 671,737. Mar. 19, 1929.

Process for producing a cast iron low in silicon, manganese, phosphorus and sulfur. M. Neumark. No. 672,001. Mar. 25, 1929.

Process for making metal objects from metallic powder. I. G. Farbenindustrie Akt.-Ges. No. 671,626. Mar. 18, 1929.

Process for recovering zinc. L. F. W. Leese. No. 671,652. Mar. 18, 1929.

Improvements to solders and to metals for plating or coating other metals. American Machine & Foundry Co. No. 671,779. Mar. 20, 1929.

Process for welding pieces of iron and steel. F. Van Wurstemberger. No. 671,891. Mar. 22, 1929.

Process for degreasing metallic objects. Udylite G.m.b.H. No. 671,909. Mar. 22, 1929.

Soldering past. Kuppers Metallwerk G.m.b.H. No. 671,911. Mar. 22,. 1929.

Improvements to processes and apparatus for applying molten metal to surfaces. T. E. Bridger. No. 671,934. Mar. 22, 1929.

Apparatus for introducing molten metal into centrifugal casting machines. A. Possenti and C. Scorza. No. 671,952. Mar. 23, 1929.

Process for producing stable electrolytic deposits on fire-refined objects. H. Stefke. No. 671,987. Mar. 23, 1929.

Improvements to electric furnaces. V. Stobie. No. 672,026. Mar. 25, 1929.

Machine for straightening sheets. F. Ungerer. No. 672,399. Apr. 2, 1929.

Process and installation for the concentration and separation of minerals, especially graphite. A. D. J. Elie. No. 672,320. Mar. 29, 1929.

Valve for the air pipes of blast furnaces. C. J. Westling. No. 672,050. Mar. 25, 1929.

Device for catching blast furnace throat dust. Vereinigte Stahlwerke Akt.-Ges. No. 672,065. Mar. 25, 1929.

Device for stirring metals and alloys in the liquid state. E. Bornand and H. A. Schlaepfer. No. 672,167. Mar. 27, 1929.

Improvements in the metallurgy of ores and other materials containing tin. E. A. Ashcroft. No. 672,229. Mar. 28, 1929.

Improvements in the metallurgy of ores and other materials containing tin. E. A. Ashcroft. No. 672,324. Mar. 29, 1929.

Process for obtaining a weldable, blow-hole-free, non-silicon steel. H. Hagemann. No. 672,373. Mar. 30, 1929.

Process for extracting non-precious metals or their salts from ores or other materials containing the metals. No. 672,416. Apr. 2, 1929.

Process and apparatus for roasting zinc blende and other metallic sulfides. Erzrostung G.m.b.H. Addition Patent No. 35,540 (First addition to Patent No. 651,692). June 22, 1928.

Apparatus for casting metals. United States Metals Refining Co. No. 672,–067. Mar. 25, 1929.

Hot process for coating iron with tin or lead. Matuschek Metallindustrie Gustau Radtke. No. 672,186. Mar. 28, 1929.

Automatic chain-welding machine. L. Ravier. No. 672,215. Mar. 28, 1929.

Improvements to welding machines. Budd Wheel Co No. 672,370. Mar. 30, 1929.

Process and composition for making molds. H. Hagemann. No. 672,372. Mar. 30, 1929.

Improvements to processes for making finned tubing. Société Alsacienne de Constructions Mecaniques à Belfort. No. 674,483. Apr. 4, 1929.

Cold-straightening machine for tubing. Maschinenfabrik Meer Akt.-Ges. No. 672,501. Apr. 4, 1929.

Improvements to arc-welding machines. Compagnie Française pour l'Exploitation des Procédés Thomson-Houston. Addition Patent No. 35,509 (Second addition to No. 602,529). Mar. 23, 1928.

Improvements to metal rings and to processes for making them. Compagnie Francaise pour l'Exploitation des Procédés Thomson-Houston. Addition Patent No. 35,536 (First addition to Patent No. 634,509). June 15, 1928.

Autogenous hole-cutting device. H. Greggersen. No. 672,799. Apr. 8, 1929.

Compressed-air molding machine head. Établissements A. Utard. No. 672,–861. Apr. 9, 1929.

Improvements to jolt molding machines. J. Morat. No. 672,897. Apr. 10, 1929.

Process for reducing sulfurous ores to metals, mattes and slags. H. Skappel. No. 672,515. Aug. 9, 1928.

Vertically movable structure particularly applicable to the lubrication of converters. Firme Bader & Salau. No. 672,547. Apr. 4, 1929.

Upper part of cast steel annealing box. Société Anonyme des Anciens Établissements Skoda à Pilzen. No. 672,758. Apr. 6, 1929.

Improvements to processes for the improvement of metals with the aid of easily fusible metals. R. Auerbach and W. Steinhorst. No. 672,759. Apr. 6, 1929.

Process for treating silicon steel. The American Rolling Mill Co. No. 672,782. Apr. 6, 1929.

Process for dephosphorizing molten metal in the converter, without overblowing, and devices for working the same. P. Ries, and F. Bicheroux. No. 672,–823. Apr. 8, 1929.

Improvements in the melting of ores. Electro Metallurgical Co. No. 672,901. Apr. 10, 1929.

Process for treating ores and various residues with simultaneous gasification of fuels. Société Fusion et Volatilization. No. 672,914. Apr. 10, 1929.

Chromium articles and process for making the same. Electrical Research Products, Inc. No. 672,620. Apr. 5, 1929.

Product for soldering metals and process for making it. J. A. Rognon. No. 672,746. July 24, 1928.

Installation for making cores for cast iron pipes. R. Ardelt. No. 672,773. Apr. 6, 1929.

Economizer for blow pipes. G. Lagonotte, and H. Jouanet. No. 672,786. Apr. 6, 1929.

Improvements to the process of pickling metals. Imperial Chemical Industries, Ltd. No. 672,809. Apr. 8, 1929.

Process for melting and deoxidizing metals and alloys, especially copper alloys. W. Reitmeister. No. 672,955. Apr. 11, 1929.

Galvanoplastic process for pieces of small dimensions, more particularly applicable to chromium plating. S. Dreyfus. No. 672,742. July 24, 1928.

Refrigerant for rotary furnaces. N. Young. No. 672,617. Apr. 5, 1929.

Improvements to combustion processes in continuously operating furnaces. F. Novelli. No. 672,940. Apr. 11, 1929.

German Patents

Subject of Invention, Patentee, Patent No., and Filing Date

Treatment of solid objects with solvents. I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. No. 483,618. Mar. 1, 1928.

Device for straightening round metal bars, especially round copper bars. Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. No. 483,619. Feb. 10, 1927.

Automatic flanging machine for cold-working round metal plates. F. Charvin, St. Etienne, Loire, France. No. 484,077. Nov. 11, 1927, in France, Sept. 17, 1927.

Deep-drawing process. A. Widmaier, Stuttgart, Germany. No. 484,227. Aug. 6, 1927.

Safety device for utensil drawing press. Zeiss-Ikon Akt.-Ges., Dresden, Germany. No. 484,078. June 8, 1928.

Nail making machine. E. Schulze, Wethmar i.W., near Lünen, Lippe, Germany. No. 484,079. Aug. 11, 1926.

Process for preventing blow-hole formation in ingots of rising low-carbon steel. Midwest Metallurgical Corp., New York, N. Y. No. 484,181. Feb. 25, 1928.

Apparatus for charging, conveying and annealing material in gas-tight containers of thermally well-conducting material in a tunnel furnace. Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. No. 484,084. Aug. 20, 1925.

Annealing furnace with movable hearth, on which the material is annealed inside hoods filled with a protective gas. Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. No. 484,085. Jan. 29, 1928.

Conveyor for annealing furnaces for annealing cast iron pipe. United States Cast Iron Pipe & Foundry Co., Burlington, No. 484,086. Feb. 25, 1927.

Apparatus for use in the process for electrically welding rails and the like by heating a poor conductor surrounding the joint to be welded by passing electric current through it. I. Block, Berlin-Steglitz, Germany No. 484,249. Apr. 13, 1927.

Process for obtaining high permeability in a loading ribbon for signal conductors, made of an alloy containing nickel and iron. Electrical Research Products, Inc., New York, N. Y. No. 483,981. Aug. 21, 1925, in the United States Nov. 6, 1924 (Claim 1 only).

Protective device for soldering irons. Telephon-Apparat-Fabrik E. Zwietusch & Co. G.m.b.H., Berlin-Charlottenburg. No. 484,188. June 30, 1927.

Electric arc welding method. Allgemeine Elektricitäts Gesellschaft, Berlin, Germany. No. 484,090. Aug. 26, 1926, in the United States Aug. 26, and Oct. 6, 1925.

Device for arc welding, using a protective gas. Allgemeine Elektricitäts Gesellschaft, Berlin, Germany. No. 484,091. (Addition to No. 484,090.) Nov. 10, 1926.

Method of welding with the electric arc in a protective atmosphere containing carbon monoxide. Allgemeine Elektricitäts Gesellschaft, Berlin, Germany. No. 484,092. (Addition to No. 484,090.) June 26, 1927, in the United States June 25, 1926.

Continuous rod casting machine. M. Douteur, La Plaine-St.-Denis, France. No. 483,907. June 22, 1927, in Belgium June 22, 1926.

Rabbling device for mechanical roasting furnaces. Balz-Erzröstung G.m.b.H., Gleiwitz, Germany. No. 484,193. (Addition to No. 482,511.) Mar. 5, 1927.

Rabbling device for roasting furnaces. T. Lang, Frankfurt a.M., Germany. No. 484,194. Feb. 9, 1928.

Process for the production of metals, with the exception of iron and tin. L. P. Basset, Paris, France. No. 484,287. June 23, 1920, in France Mar. 10, 1919.

Preparation of fine zinciferous material for dead-roast sintering. Cie. des Metaux Overpelt-Lommel, Overpelt-lez-Neerpelt, Belgium. No. 484,288. Mar. 17, 1927, in Belgium Jan. 26, 1927.

Process and apparatus for carrying out fusion electrolyses. I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. No. 484,289. Apr. 15, 1928.

Process for the electrolytic recovery of pure aluminum in compact form from crude aluminum, alloys, and the like. Aluminium-Industrie-Akt.-Ges., Neuhausen, Switzerland. No. 484,196. Nov. 23, 1926.

Furnace for the production of aluminum by fusion electrolysis. Vereinigte Aluminium Werke Akt.-Ges., Lautawerk, Lausitz, Germany. No. 485,–197. Mar. 2, 1929.

Process for the removal of halogen ions, especially from salt solutions for the electrodeposition of metals. Metallgesellschaft Akt.-Ges., Frankfurt a.M., Germany. No. 484,198. Dec. 2, 1927.

Improvement of the mechanical properties of aluminum and aluminum alloys containing iron. Erftwerk Akt.-Ges., Grevenbroich, Niederheim, Germany. No. 484,097. Aug. 30, 1927.

Process for changing the coefficient of thermal expansion of metals. Siemens & Halske Akt.-Ges., Berlin-Siemensstadt, Germany. No. 484,199. Sept. 23, 1926.

Apparatus for annealing copper wires and the like. J. Jungblut, Duisburg Neudorf, Germany. No. 484,098. July 25, 1928.

Process for the electrodeposition of chromium on iron, steel or nickel objects. Metals Protection Corporation, Indianapolis, Ind. No. 484,206. Aug. 28, 1926, in the United States Mar. 5, 1926.

Rotary tubular furnace for burning, roasting, and sintering all kinds of material. G. Polysius Akt.-Ges., Dessau, Germany. No. 484,162. Feb. 19, 1928.

Wire rod rolling mill. Maschinenfabriks-Akt.-Ges. Richard Herz, Vienna, Austria. No. 484,430. Oct. 30, 1927, in Austria Nov. 3, 1926.

Rod or tube press. A. Kreidler, Stuttgart, Germany. No. 484,649. Aug. 1, 1925.

Pressing tool with a fixed die, a movable die, and a matrix. F. Humphries, Parkstone, Dorsetshire, England. No. 484,658. Nov. 26, 1926, in Great Britain Nov. 26, 1925.

Disk rolling mill. Budd Wheel Co., Philadelphia, Pa. No. 484,354. Apr. 3, 1927, in the United States Apr. 6, 1926.

Burner for hardening gears. Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany No. 484,365. May 11, 1927, in the United States May 27, 1926.

Tilting enclosed arc furnace. E. F. Russ, Köln, Germany. No. 484,587, Dec. 23, 1925.

Rotary, approximately pear-shaped melting furnace with oil or gas firing. W. Buess, Hannover, Germany. No. 484,744. Apr. 4, 1928.

Melting crucible built up of two or more layers of different materials. Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. No. 484,386. Dec. 10, 1927, in the United States June 4, 1927.

Molding machine. W. H. Nicholls, Brooklyn, N. Y. No. 484,593. Dec. 9, 1927.

Die casting machine. Aluminum Die-Casting Corp., Garwood, N. J. No. 484,745. Jan. 12, 1927, in the United States Jan. 22, 1926.

Device for feeding material to rotary furnaces. Fried. Krupp Grusonwerk Akt.-Ges., Madgeburg-Buckau, Germany. No. 484,393. Apr. 25, 1928.

Deoxidizing agent for metals and alloys, especially copper. Siemens & Halske Akt.-Ges., Berlin-Siemensstadt, Germany. No. 484,394. Apr. 12, 1927.

Production of alloys of the system copper-zinc-nickel. A. Bielinki and J. J. Coomanns, Brussels, Belgium. No. 484,557. May 8, 1929.

Magnesium-containing aluminum alloy which is improvable by annealing, quenching and ageing. W. Kroll, Luxembourg. No. 484,395. Sept. 8, 1925.

Forging machine. O. Georg, Herdecke a.d.Ruhr. Germany. No. 484,493. Apr. 20, 1928.

Method of soldering iron and steel parts. F. von Wurstemberger, Zurich, Switzerland. No. 484,494. Apr. 4, 1928.

Hard-solder paste. Brasvit-Werke G.m.b.H., Eydtkuhnen, Ostpr., Germany. No. 484,495. Jan. 26, 1927.

Preheating with hot gases the ends of rails and similar objects which are to be welded aluminothermically. W. Brewitt, Berlin-Cöpenick, Germany. No. 484,496. Mar. 16, 1928.

Torch cutting-machine. A. Godfrey, London, England. No. 484,497. July 2, 1927, in Great Britain Dec. 21, 1926.

Process for making molded refractory objects of magnesite. United States Metals Refining Co., Carteret, N. J. No. 484,554. Dec. 8, 1925, in the United States Dec. 10, 1924.

Process for making furnace linings. G. Polysius Akt.-Ges., Dessau, Germany. No. 484,531. Sept. 29, 1927.

Conveyor installations for continuously operating furnaces. Allgemeine Elektricitäts Gesellschaft, Berlin, Germany. No. 484,425. June 29, 1928.

Matrix for the deep-drawing process. E. Schwartz, Stöhna-Erlhof, Bez. Leipzig, Germany. No. 485,064. Dec. 22, 1928.

Production of articles from perforated sheets or hollow blanks by use of a grooved mandrel in the rolling mill. F. im Schlaa, Iserlohn, Westf., Germany. No. 475,065. July 13, 1928.

Process for making alkali- and acid-proof rubber coatings on metallic objects. F. Ahrens, Hildesheim, and Harzer Aschenwerke G.m.b.H., Bornum am Harz, Germany. No. 484,894. May 19, 1925.

Attachment of heating elements in electric furnaces. Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. No. 485,084. Nov. 29, 1925, in the United States Apr. 24, June 33, and Sept. 12, 1925.

Process for making electric furnace electrodes. Siemens-Planiawerke Akt.-Ges. für Kohlefabrikate, Berlin-Lichtenberg, Germany. No. 485,085. Mar. 21, 1925.

Device for automatically setting the electrodes of electric melting furnaces. Demag Akt.-Ges., Duisburg, Germany. No. 484,914. June 11, 1926.

Apparatus for arc welding with the use of a protective gas. Allgemeine Elektricitäts Gesellschaft, Berlin, Germany. No. 485,215. (Addition to No. 484,091.) June 3, 1927.

Vestibule between shaft and fore-hearth, and back of the fore-hearth with tap hole for the metal. A. Uhe, Brandenburg a.d.H., Germany. No. 485,220. June 10, 1928.

Process for making steel castings. Gesellschaft für Förderanlagen Ernst Heckel m.b.H., Saarbrücken, Germany. No. 485,127. Apr. 23, 1925.

Apparatus for working the centrifugal casting process. W. Raym, Deuz, Westf., Germany. No. 484,919. (Addition to No. 459,965.) June 20, 1928.

Pressure-casting machine in which the metal flows into the multi-part mold under a head of molten metal and is compressed by drawing together the parts of the mold. F. J. Haas, Stuttgart, Germany. No. 485,221. May 18, 1926.

Introduction of additions during the poling of copper. O. Nielsen, Ilsenburg, Harz, Germany. No. 485,228. (Addition to No. 428,024.) Jan. 27, 1927.

Cooling bed. B. Quast, Rodenkirchen near Köln, Germany. No. 485,263. July 31, 1928.

Vertical draw-press for making tubing. Adolf Kreuser G.m.b.H., Hamm i.W., Germany. No. 485,366. Sept. 22, 1928.

Process for the production of iron by the thermal decomposition of iron carbonyl. I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. No. 485,639. Dec. 16, 1924.

Rotary drum for mixing two or more substances, especially ore concentrates, slime or the like with powdered coal or coke. H. Eriksson, Sköldinge, Sweden. No. 485,657. Aug. 17, 1927, in Sweden June 16, 1927.

Means for accelerating the annealing process in wire-annealing furnaces. Akt.-Ges. Brown, Boveri & Cie., Baden, Switzerland. No. 485,502. June 26, 1926.

Movable charging top for bright-annealing furnaces. Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. No. 485,603. Nov. 3, 1925.

Interchangeable suspension device for the heating resistances of electric furnaces. Allgemeine Elektricitäts Gesellschaft, Berlin, Germany. No. 485,287. Mar. 30, 1928.

Electric alarm and protective device for avoiding irregularities in cooling the transformers of induction furnaces. E. F. Russ, Köln, Germany. No. 485,550. Feb. 21, 1926.

Process for producing stable coatings on carbon electrodes. Siemens-Planiawerke Akt.-Ges. für Kohlefabrikate, Berlin-Lichtenberg, Germany. No. 485,-288. May 9, 1928.

Core-making machine. H. Hepperle, Mülheim a.d. Ruhr-Speldorf, Germany. No. 485,570. Nov. 6, 1925.

Air-cooled rabbling mechanism for roasting furnaces. Balz-Erzröstung G.m.b.H., Gleiwitz, Germany. No. 485,618. (Addition to Patent No. 482,511.) Dec. 6, 1927.

Rotary tubular furnace for carrying out exothermic or combined exothermic and endothermic reactions. T. Lang, Frankfurt a.M., Germany. No. 485,529. (Addition to Patent No. 483,428.) Feb. 15, 1927.

Furnace for heat treating materials, especially for roasting ores. I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. No. 485,456. Aug. 17, 1926.

Process for producing metallic and metalloidal alloys and compounds. L. P. Basset, Paris, France. No. 485,430. June 23, 1920, in France Mar. 10, 1919 and Feb. 20, 1920.

Partition for separating the products of electrolysis in the fusion electrolysis of chlorides, especially magnesium chloride. I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. No. 485,290. Dec. 24, 1927.

Process for recovering magnesium by fusion electrolysis. I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. No. 485,431. Jan. 22, 1927.

Process for working reciprocating and rotating baths. Langbein-Pfanhauser-werke Akt.-Ges., Leipzig-Sellerhausen, Germany. No. 485,294. Feb. 12, 1927.

Apparatus for automatically and continuously carrying tubs, utensils and baskets through galvanizing and other liquid baths. G. Buchert, Piegnitz, Germany. No. 485,295. (Addition to No. 461,266.) Feb. 25, 1928.

Process for impregnating objects made of metal or other suitable materials with aluminum or aluminum alloys. The Expanded Metal Co., Ltd., London England. No. 485,296. Mar. 3, 1927, in Great Britain Mar. 17, and Dec. 14, 1926.

Process for treating iron and steel objects. Metals Protection Corp., Indianapolis, Ind. No. 485,622. Aug. 28, 1926, in the United States Jan. 25, 1926.

Reversing drive for the reciprocating discharge devices of shaft furnaces. Fried. Krupp Grusonwerk Akt.-Ges., Madgeburg-Buckau, Germany. No. 485,650. Apr. 14, 1926.

Electric drive for the feed mechanism of pilger rolling mills. Demag Akt.-Ges.-Duisburg, Germany. No. 485,986. Feb. 7, 1926.

Three-part bearing housing for the roller bearings of rolling mills. Schloemann Akt.-Ges., Düsseldorf, Germany. No. 485,987. (Addition to No. 452,-544.) July 3, 1924.

Rollway with two or more guides placed side by side, for the rolled material. Fried. Krupp Grusonwerk Akt.-Ges., Magdeburg-Buckau, Germany. No. 485,999. (Addition to No. 470,535.) Feb. 22, 1928.

Control for the drive of reversible machinery. Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. No. 486,000. Sept. 14, 1928, in the United States Sept. 23, 1927.

Method of cross-feeding the wire on to the blocks of multiple wire-drawing machines. W. Nacken, Grüna, near Chemnitz, Sa., Germany. No. 485,829. May 9, 1928.

Reel for strip-rolling mill. F. Grah, Sundwig, Kr. Iserlohn, Germany. No. 485,830. Dec. 28, 1927.

Tube-drawing press. Press- und Walzwerk Akt.-Ges., Reisholz, Germany. No. 485,892. (Addition to No. 447,197.) Dec. 12, 1928, in France Feb. 12, 1927.

Method of making pipe bends and other forgings. Eumoco Akt.-Ges. für Maschinenbau, Schlebusch-Manfort, Germany. No. 485,705. Mar. 8, 1927.

Finger-protective device for presses. B. Schöniger, Beierfeld, Germany. No. 486,001. Nov. 29, 1928.

Rolling mill for the fabrication of balls. O. Hering, Essen-Bredeney, Germany. No. 485,767. Aug. 3, 1926.

Blast furnace with closure means at the bottom of the shaft. Y. Murakami, Togoshi, Japan. No. 485,834. Sept. 22, 1926, in Japan Sept. 28, 1925.

Rotary-tubular and melting furnace installation for the direct production of cast iron or steel from iron ores. P. J. Peyrachon, La Felguera, Austurias, Spain. No. 485,835. Sept. 19, 1926, in France July 13, 1926.

Sand-slinging molding machine. F. K. Axmann, Köln-Ehrenfeld, Germany. No. 485,735. Apr. 17, 1928.

Longitudinally-displaceable pouring trough for a horizontal centrifugal pipe-casting machine. Compagnie Générale des Conduites d'Eau, Liege, Belgium. No. 486,025. Dec. 17, 1927, in Belgium Dec. 10, 1927.

Mechanism for conveying suspended objects through baths. Siemens & Halske Akt.-Ges., Berlin-Siemensstadt, Germany. No. 485,744. Oct. 6, 1927.

Cutting holes by burning. H. Greggersen and H. Propfe & Co., m.b.H., Hamburg, Germany. No. 485,928. June 6, 1928.

Process for producing aluminum coatings on rods and wire. F. Jordan, Wickede, Ruhr, Germany. No. 485,801. Dec. 16, 1927.

Flotation process, especially for carbonaceous material. L. Schmeer, Saarbrücken, Germany. No. 486,326. July 26, 1922.

Mechanism for throwing cold-rolling mills in or out of gear. F. Grah, Hemer, Kr. Iserlohn, Germany. No. 486,171. Nov. 30, 1928.

Fine adjustment for the upper roll of pilger rolling mills. E. Röber, Düsseldorf, Germany. No. 486,172. Oct. 20, 1928.

Fine adjustment for the upper roll of pilger rolling mills. E. Röber, Düsseldorf, Germany. No. 486,173. (Addition to No. 486,172.) Dec. 18, 1928.

Independent electric drive for the rollers of the roller beds of rolling mills. Maschinenfabrik Sack G.m.b.H., Düsseldorf-Rath, Germany. No. 486,162. Sept. 22, 1925.

Device for shoving rolled material being conveyed on a delivery table. Demag Akt.-Ges., Duisburg, Germany. No. 486,340. Oct. 9, 1928.

Dies for making ribs in boiler plates and the like. W. M. Connery, Philadelphia, Pa. No. 486,341. July 12, 1925, in the United States July 16, 1924.

Device for preventing explosions in the blast pipes of blast furnaces by automatic closing of the blast pipes and automatic opening of a valve. Zimmermann & Jansen G.m.b.H., Düren, Rheinland, Germany. No. 486,234. Jan. 21, 1928.

Regenerative hearth furnace. Witkowitzer Bergbau- und Eisenhütten-Gewerk. schaft, Witkowitz, and C. Salat, Mährisch Ostrau. No. 486,235. Apr-1, 1926.

Production of objects having great strength and high chemical resistance. Deutsche Edelstahlwerke Akt.-Ges., Bochum, Germany. No. 486,285. Jan. 11, 1922.

Water cooled rails for heating furnaces. Friedrich Siemens Akt.-Ges., Berlin, Germany. No. 486,180. (Addition to No. 387,705.) June 26, 1927.

Electrode for resistance welding machines. Allgemeine Elektricitäts Gesellschaft, Berlin, Germany. No. 486,247. Sept. 24, 1926, in Austria Sept. 25, and Dec. 10, 1925.

Molding machine. Société Anonyme des Usines de Rosières (Cher.), Bourges Cher, France. No. 486,199. Aug. 31, 1928, in France Aug. 31, 1927.

Process for removing rust and scale from glass molds and glass-working tools. Glasfabriken und Raffinieren Josef Inwald Akt.-Ges., Rusolfshütte-Teplitz, Czecho-Slovakia. No. 486,148. Aug. 7, 1926.

Device for setting and readjusting the blades of metal-shears, especially of heavy machine-driven plate shears. Schleifenbaum & Steinmetz, Weidenau, Sieg, Germany. No. 486,385. Sept. 8, 1925.

Shear for cutting wide strips of moving rolled material. J. Hahn, Cleveland, Ohio. No. 486,386. July 4, 1928, in the United States Mar. 10, 1928.

Device for granulating molten slag. F. Spies, Velsen, Netherlands. No. 486,336. May 17, 1925.

Process for making metal-sheathed electrodes. B. Redlich, Feldkirchen, near Munich, Germany. No. 484,545. June 26, 1925.

Brinell hardness testing instrument. E. R. Mayer, Stuttgart, Germany. No. 485,058. Nov. 9, 1922.

Process for preparing electrolytic chromium plating baths. Siemens & Halske Akt.-Ges., Berlin-Siemensstadt, Germany. No. 484,977. Oct. 18, 1927.

Process for producing beryllium coatings on metals or alloys. Siemens & Halske Akt.-Ges., Berlin-Siemensstadt, Germany. No. 485,103. Aug. 21, 1926.

Process for coating copper or brass objects. Metallwarenfabrik Christian Wagner G.m.b.H., Esslingen a.N., Germany. No. 485,160. (Addition to No. 450,218.) Sept. 11, 1928.

Forging press drive. Allgemeine Elektricitäts Gesellschaft, Berlin, Germany. No. 485,021. (Addition to No. 436,801.) Oct. 17, 1924.

Machine for classifying bronze powder according to grain size. Friedrich Sporer Maschinenfabrik, Nürnberg, Germany. No. 485,130. Apr. 21, 1925.

Norwegian Patents

Subject of Invention, Patentee, Patent No., and Filing Date

Process for the production of metallic aluminum by the electrolytic reduction of alumina. The Aluminum Company of America, Pittsburgh, Pa. No 46,812. Apr. 7, 1925.

Electric annealing furnace. Siemens-Schuckertwerke G.m.b.H., Berlin-Siemensstadt, Germany. No. 46,841. July 24, 1925.

Process for the concentration of floatable materials, such as ores, coal, graphite and the like. W. Schäfer and Erz u. Kohle-Flotation G.m.b.H., Bochum, Germany. No. 46,860. Mar. 1, 1928.

Process for making castings, especially bearings, of different metals. Eisen- u. Stahlwerk Walter Peyinghaus, Egge, near Volmarstein a.d.Ruhr, Germany. No. 46,900. Nov. 6, 1926.

Process and apparatus for the continuous expulsion of arsenic from arsenical ores. Patentaktiebolaget Gröndal-Ramén, Stockholm, Sweden. No. 46,991. Apr. 4, 1928.

Portable tapping device for electric furnaces. Siemens & Halske Akt.-Ges., Berlin-Siemensstadt, Germany. No. 46,999. July 30, 1928.

Rotary furnace for carrying out chemical processes. L. Tocco and M. Landi, Paris, France. No. 47,001. June 15, 1926.

Process for electrolyzing fused baths. R. J. McNitt, Perth Amboy, N. J. No. 47,002. Nov. 10, 1924.

Process for the electrolytic recovery of pure aluminum from crude aluminum, alloys and the like. Aluminium Industrie Akt.-Ges., Neuhausen, Switzerland. No. 47,003. Sept. 19, 1927.

Process for the surface treatment of metallic objects. A. Pacz, Cleveland, Ohio. No. 47,004. Dec. 21, 1926.

Process for the production or regeneration of a rust-preventive bath containing phosphorus. Société Continentale Parker, Clichy, France. No. 47,041. Oct. 28, 1926.

Swedish Patents

Subject of Invention, Patentee, Patent No., and Filing Date

Construction of high-voltage electric furnaces. A/S Norsk Staal (Elektrisk-Gas-Reduktion), Oslo, Norway. No. 68,422. June 2, 1926.

Method of straightening sheets. F. Ungerer, Pforzheim, Germany. No. 68,-524. Aug. 28, 1928.

Process and apparatus for driving off arsenic from arsenical ores. Patentaktiebolaget Gröndal-Ramén, Stockholm, Sweden. No. 68,506. (Addition to No. 64,726.) Jan. 5, 1927.

Tilting sintering furnace. E. Greenawalt, New York, N. Y. No. 68,507. Dec. 17, 1928.

Process for the production of light metals by the electrolysis of fused chlorides. A. C. Jessup, Paris, France. No. 68,581. July 27, 1926, abroad Aug. 5, 1925.

Process for impregnating a metal or other material with aluminum or aluminum alloys. The Expanded Metal Company, Ltd., London, England. No. 68,588. Feb. 22, 1927, abroad Dec. 14, 1926.

Process for preparing pickling baths for metals, especially iron and steel. V. Bertleff, Zilina, Czecho-Slovakia. No. 68,589. June 28, 1928, abroad July 9, 1927 and Feb. 13 and June 9, 1928.

Swiss Patents

Subject of Invention, Patentee, Patent No., and Filing Date

Electrically welded still for refining oils and for other purposes and method of making the same. A. O. Smith Corp., Milwaukee, Wis. No. 133,788 Jan. 6, 1928.

Electrically welded still for refining oils and for other purposes and method of making the same. A. O. Smith Corp., Milwaukee, Wis. No. 133,789. Jan. 6, 1928.

Process for rendering a metallic object capable of receiving a perfectly adherent metallic plating. G. Fueslin, Geneva, Switzerland. No. 133,813. June 13, 1928.

Inductive and ohmic series resistances for direct-current arc-welding. O. Schuchmacher, Hamburg, Germany. No. 133,853. Jan. 9, 1928, in Germany Jan. 11, and July 13, 1927.

Heat treating furnace. The Surface Combustion Co., Toledo, Ohio. No. 133,-855. May 29, 1928, in the United States June 2, 1927.

Process for sulfur-proofing metallic conductors for cables, etc. F. Kirschner and J. Hess, Vienna, Austria. No. 133,911. June 27, 1927, in Austria July 3, 1926 and Apr. 14, 1927.

Electric annealing furnace. Heraeus Vacuumschmelze Akt.-Ges., Berlin-Siemensstadt, Germany. No. 133,928. Oct. 25, 1928, in Germany Dec. 12, 1927.

Process for the production of coatings on metallic objects. Dr. Otto Sprenger, Patentverwertung Jirotka m.b.H., Vaduz, Liechtenstein. No. 134,113. Mar. 22, 1928.

Acid-proof iron alloy. Oesterreichische Schmidstahlwerke Akt.-Ges., Vienna, Austria. No. 134,138. Apr. 10, 1928, in Austria Apr. 15, 1927.

Rotary drum furnace. K. Schmidt, Neckarsulm, Germany. No. 134,139. Sept. 13, 1928, in Germany Sept. 21, 1927.

Process for casting a liquid material in a mold and installation for working the same. Fonderies et Forges de Crans S.A., Cran-Gevrier, near Annecy (Haute-Savoie) France. No. 134,140. May 4, 1928.

Apparatus for mixing foundry sand. W. H. Nicholls, Brooklyn, N. Y. No. 134,141. June 22, 1928.

Welding flux for aluminum. W. Reuss., Mannheim, Germany. No. 134,142. Nov. 7, 1927.

Process and apparatus for cleaning and degreasing metallic objects. Chemisches Werk Zurich Akt.-Ges., Zurich, Switzerland. No. 134,375. June 15, 1928.

Process for refining metal mixtures. H. Hauser, Schaffhausen, Switzerland. No. 134,414. July 26, 1928.

Device for supporting the delivery means of centrifugal casting machines. Vereinigte Stahlwerke Akt.-Ges., Düsseldorf, Germany. No. 134,415. May 5, 1928.

Centrifugal casting machine for making hollow bodies. Societá Alti Forni, Fonderie, Acciairie e Ferriere Franchi Gregorini, Brescia, Italy. No. 134,416. June 12, 1928.

Process for casting magnesium and magnesium alloys. I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. No. 134,417. July 31, 1928.

Piston-actuated casting machine for difficultly-fusible metals. M. C. Valls and J. S. Esteller, Barcelona, Spain. No. 134,418. Aug. 8, 1928.

Process for hot-rolling metals. Sundwiger Eisenhütte Maschinenbau Akt.-Ges., Sundwig Kr. Iserlohn, Germany. No. 134,419. Apr. 26, 1928, in Germany May 2, 1927.

Device for moving suspended articles through baths, especially electrolytic baths. Siemens & Halske Akt.-Ges., Berlin-Siemensstadt, Germany. No. 134,-630. Sept. 29, 1928, in Germany Oct. 5, 1927 and Feb. 18, 1928.

Process for preventing hardening of certain portions of objects to be hardened by nitirization. Aubert Duval Frères, Paris, France. No. 134,631. Mar. 12, 1928, in Germany May 10, 1927.

Process for cleaning metallic objects, especially for cleaning rust from iron and steel. W. H. Cole, Paris, France. No. 134,632. Mar. 17, 1928, in Great Britain Aug. 22, 1927.

Device for measuring the thickness of strips in strip-rolling mills. Metallwerke Akt.-Ges., Dornach, near Basel, Switzerland. No. 134,663. Nov. 23, 1928.

Device for testing the tightness of welded seams. Gebrüder Sulzer Akt.-Ges.. Winterthur, Switzerland. No. 134,666. Jan. 7, 1929.

Process for briquetting iron ore concentrates. P. Gredt, Luxembourg, Grand Duchy of Luxembourg. No. 134,676. Feb. 3, 1928.

Process for concentrating chromium ores. I. G. Farbenindustrie, Frankfurt a.M., Germany. No. 134,677. Mar. 22, 1928.

Corrosion-proof aluminum alloy. Vereinigte Aluminium Werke Akt.-Ges., Lautawerk/Lausitz, Germany. No. 134,678. Sept. 10, 1927, in Germany Sept. 18, 1926.

Process and apparatus for separating alloyed metals by chlorination. G. A Favre, Lyons, France. No. 134,679. Jan. 18, 1928.

Process for the preparation of liquid alloys of sodium and potassium. L. Hackspill and E. Rinck, Strassbourg, France. No. 134,680. July 13, 1928.

Process, especially for welding and soldering by radiant heat. E. Schröder, Berlin, Germany. No. 134,681. June 20, 1928, in Germany June 28, 1927.

Multiple wire-drawing machine for drawing fine wire. Drahtindustrie Peter Darmstadt & Co. G.m.b.H., Frankfurt a.M., Germany. No. 134,682. June 26, 1928.

Process and machine for straightening sheets. F. Ungerer, Pforzheim, Germany. No. 134,685. Sept. 4, 1928.

Process for producing metallic structural elements with increase in the elastic limit or yield point of the metal. G. Kerékgyárto, Budapest, Hungary. No. 134,688. July 20, 1928, in Hungary Aug. 11, 1927.

Cooling means for bright-annealing furnaces. Siemens & Halske Akt.-Ges., Berlin-Siemensstadt, Germany. No. 134,689. Nov. 5, 1928.

Personals

M. A. Grossman, chief metallurgist of the Central Alloy Steel Corporation, Massillon, Ohio, has sailed for Europe to continue his study of the special European steels which the company is preparing to produce in this country.

Paul D. Merica has been appointed technical assistant to the president of the International Nickel Company, Inc., New York. Formerly he was assistant manager of that company's development and research department.

R. L. Aggassiz, Chairman of the Board of the Calumet & Hecla Consolidated Copper Company, of Boston, was reelected president of the Copper & Brass Research Association at the ninth annual meeting of that organization, held Oct. 24th, at its offices, 25 Broadway, New York.

Two additional producing member companies were admitted to membership. They are Copper Range Company and The Granby Consolidated Mining, Smelting & Power Co., Ltd.

John M. Gaines, Jr., formerly associate physical chemist, Pittsburgh Experimental Station, U. S. Bureau of Mines, has resigned to engage in some advanced study at M. I. T.

R. R. Dean, formerly associated with the Western Electric Company, Hawthorne Works, Chicago, is now chief engineer, Metallurgical Division, U. S. Bureau of Mines. Dean attended the Universities of Missouri, Chicago and Harvard. Before joining the Western Electric Company, he was in the employ of the Anaconda Copper Mining Company and the American Zinc, Lead and Smelting Company.

E. F. Adriance has resigned as assistant metallurgist for the Remington Typewriter Company, Ilion, N. Y., to accept the position of chief metallurgist for the W. A. Riddell Company, Bucyrus, Ohio.

E. R. Young, formerly with the Detroit Steel Casting Company, is now attached to the Detroit district office of the Climax Molybdenum Company as metallurgical engineer.

James F. Croft has resigned his position as metallurgist Mackintosh-Hemphill Company, Pittsburgh, Pa., to accept a position in a like capacity with the Birdsboro Steel Foundry and Machine Company, Birdsboro, Pa., assuming charge of the roll department.

Sam Tour, formerly metallurgist for the Doehler Die Casting Corporation and later engaged in general metallurgical consulting work, has merged his business with that of Lucius Pitkin, Inc. Mr. Tour has been elected a vice-president of the company and has taken charge of the branch office at Batavia, N. Y.

P. E. McKinney, formerly metallurgist at the U. S. Naval Gun Factory, Washington, is now associated with the Bethlehem Steel Company, as metallurgical engineer at Bethlehem, Pa.

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Reviews of Manufacturers' Literature

In this department we shall list each month a selection of the catalogs, books, treatises and other printed matter issued by manufacturers which, in our judgment, should be of interest to the readers of METALS & ALLOYS. *Unless otherwise noted, any of the items listed may be secured free upon application to the issuing firm. Manufacturers who have not yet sent in their printed matter for consideration by the editor of this department are invited to do so, and it is suggested that* METALS & ALLOYS *be placed on the regular mailing list so that advance copies of any material of interest to the metallurgical world may automatically come to this department.*—EDITOR.

The New Way.—New book containing facts about Smith Welded Line Pipe. Also contains valuable engineering data, tables of comparison, illustrations of carloading, tables of test pressure and weights, field bending tests and chart showing application of expansion joints. A. O. Smith Corporation, Milwaukee, Wisconsin.

Hausfeld Metal Melting Furnaces.—Catalog No. 27 gives full information on this subject. Profusely illustrated. Prices. The Campbell-Hausfeld Co., Harrison, Ohio.

Properties of Haynes Stellite.—Interesting booklet containing data based upon investigations by the Union Carbide and Carbon Research Laboratories, Inc. assembled to make information on Haynes Stellite readily available to engineers and scientists in the manufacturing industries. Haynes Stellite Co., Kokomo, Indiana.

Published by the same firm, "Stelliting of Wearing Parts in Cement Mills."

The Foundry Oven Bulletin, No. 26-F.—Illustrates and describes this type of oven for industrial uses. Young Brothers Company, 6500 Mack Avenue, Detroit, Mich.

Published by the same firm, "Industrial Ovens, Bulletin No. 28-J" illustrates and describes ovens for baked finishes.

The Nazel Hammer Book.—Looseleaf catalog (1929 Edition) contains illustrations, weights and dimensions. Detailed operating description, general construction Nazel Engineering & Machine Works, 404 North 5th St., Philadelphia, Pa.

Combined Equipment and General Foundry Supply Catalog, No. 51.—This general catalog contains everything needed in the foundry. Profusely illustrated, tables of sizes and dimensions. A very useful and valuable document. The S. Obermayer Co., 2563 West 18th St., Chicago. Ill.

Published by the same firm, "Ramtite, The Plastic Monolithic Furnace Lining," "Hott-Patch High Temperature Furnace Cement," "Spray The Surface and You Save the Wall."

Inland.—Comprehensive catalog, leather binding, illustrating and describing full line of pig iron open hearth steel and rail carbon steel. Specifications. Fully indexed. Inland Steel Co., First National Bank Building, Chicago, Ill.

Published by the same firm, "Inland Steel Sheets," the story of a workable enduring and useful sheet metal.

Ketos.—Booklet illustrating and describing crucible and electric tool and alloy steels. (Fifth revised edition.) Data on Government tests. Halcomb Steel Co., Syracuse, N. Y.

Heppenstall.—Valuable information is contained in this handy pocket size looseleaf binder on high grade acid, open hearth alloy and carbon steels for many uses. Specifications. Diagrams, Charts. Heppenstall Forge Co., Bridgeport, Conn.

1001 Alloy Formulas, Their Manufacture Properties and Industrial Application.—By Ernest G. Jarvis, F.A.I.C. Information on this subject put in shape as a handy reference, compiled alphabetically with foot note and reference marks explaining how the alloys can be compounded in the best way to produce good castings. Chapters on deoxidizers for the various alloys, also information as to tenacity, elongations, hardness, etc., has also been included. Niagara Falls Smelting & Refining Corp., 2204 Elmwood Ave., Buffalo, N. Y.

Published by the same firm, "U. S. Navy Specifications for Non-Ferrous Alloys," "How to Make Manganese Bronze," "S.A.E." Specifications and Formulas for Non-Ferrous Metals."

"Wire Cloth — All Meshes — All Weaves — All Lengths — All Widths."—New Bulletin just off the press showing number of typical examples of wire cloth varying from 1″ space to 300 mesh. Tells about 400 mesh wire cloth which is the finest in the world—160,000 square holes per square inch. Gives the latest information on Gasketed Metallic Filter Cloth, on the new Newark Testing Sieve, with inside rounded corners and all soldering on outside, on Newark Foundry Riddles, Newark Renewable Bottom Sieve and Newark Metallic Filter Cloth. Newark Wire Cloth Co., 351 Verona Ave., Newark, N. J.

Laboratory Apparatus and Chemicals.—Catalog No. 4. Handsome comprehensive catalog, stiff cloth binding, containing full line of apparatus and chemicals for chemical, biological, bacteriological, metallurgical and clinical laboratories. Also contains section devoted to reagents and chemicals. Thumb indexed. A valuable piece of printed matter. Will Corporation, Rochester, N. Y.

D. F. C. Refractories.—Catalog No. 141 contains origin and methods of making DFC refractories, Brands of DFC fire brick and their characteristics, standard fire brick shapes, rectangular tile, boiler and baffle tile, kiln linings, milled fire clay and crushed fire brick, standard practices governing special shapes, notes on fire brick construction, data on temperatures, weights and measurements, DFC refractory mortars and bonding materials, PX-33 moldable furnace lining. The Denver Fire Clay Co., Denver, Colo.

Published by the same firm, "D.F.C. Flat Arches, Sectional Walls for Furnace Construction." Also "D.F.C. Oil Burners."

Calco Service.—Looseleaf binder containing the following bulletins No 1, "Strength of Seamless Steel Tubing at Cracking Still Temperatures," No. 2, "The Elimination of Swollen and Ruptured Tubes in Cracking Stills," No. 3, "Prevention of Corrosion in Cracking Still Equipment," No. 4, "Prevention of Oxidation in Cracking Still Equipment," No. 5, "The Selection of Material For Cracking Still Construction," No. 6, "Manufacture and Inspection of Seamless Steel Tubing for Cracking Still Operation," No. 7, "The Design and Use of Tube Supports in Cracking Stills." The Calorizing Co., Pittsburgh, Pa.

Perlit (High Test Cast Iron).—Buletin, just off the press describing Perlit, a high test cast iron without alloy. The Dursar Corporation, 60 Park Place, Newark, N. J.

Hybnickel Alloys.—Booklet containing a few typical illustrations showing application of various Hybnickel Alloys for extreme service. Victor Hybinette, Wilmington, Dela.

Nugent Steel Castings.—Five new bulletins as follows: No. 115 "6928 lbs. of New Materials are Required to Produce 1 Ton of Nugent Steel Castings," No. 116, "Announcing the Nucombe One Piece Locomotive Spring Hanger," No. 117, "Who's Who in a Steel Foundry," No. 119, "Improving an Age-Old Product," No. 121, "He Who Goes Under the Earth Expects Severest Service." The Nugent Steel Castings Co., Wood and 31st Sts., Chicago, Ill.

Duraloy (The original Chrome Iron).—Descriptive bulletins as follows. No. 276, "Duraloy For Resistance to Oxidation, Corrosion and Abrasion—General Information" No. 277, "Duraloy Stainless for Resistance to Oxidation and Corrosion," No. 279, Duraloy "in the Mining Industry for Resistance to Corrosion by Acid Mine Water and to Abrasion," No. 278, "Duraloy, Its Relation to Corroding Media," No. 2811, "Duraloy Recuperators," No. 2710, Duraloy All-Metal Baffles for Steam Boilers, Oil Stills and the Like. The Duraloy Co., 47 Terminal Way, Pittsburgh, Pa.

Purite.—Bulletins as follows: No. 275, "Purite in Cupola Practice," No. 285, "Refining Iron with Purite," No. 286, "Purite in Malleable," No. 287, "Desulphurizing with Purite," Bulletin No. 288, "Purite in Brass Melting." All descripting of their titles. The Mathieson Alkali Works (Inc.), 250 Park Avenue, New York, N. Y.

Hagan Furnaces.—Series of leaflets illustrating and describing various types of these furnaces. George J. Hagan Co., Chamber of Commerce Bldg., Pittsburgh, Pa.

Acheson Electrodes.—Series of booklets as follows, "For Electrolytic Purposes," "Standard and Special Sizes," "Their Nature and Properties," "Orders and Shipments." Acheson Graphite Corp., Niagara Falls, N. Y.

The Manganese Steel.—Booklet on the subject of its history, what it is, what it does, what it's for, etc. American Manganese Steel Co., Chicago, Ill

Published by the same firm "Fahralloy for Every Heat and Corrosion Resistant Purpose."

Evaporation.—Leaflet describing Leadclad, its properties and advantages. Wheeling Metal & Mfg. Co., Wheeling, West Va.

Published by the same firm, "Leadclad Flat Sheets," "Why Leadclad?" "Leadclad Corrugated Sheets."

Oxy-Acetylene Tips.—Monthly magazine issued in the interests of Oxwelded Steel Building. The September issue contains an interesting article on large steel building completely Oxwelded. The first major industrial structure to be fabricated by Oxwelding under usual procedure of construction. Also contains many other interesting articles and illustrations. The Linde Air Products Company, 30 East 42nd Street, New York, N. Y.

Dependability in Steel Castings.—Very interesting booklet illustrating and describing the process of making a steel casting. Also contains temperature control chart showing furnace and load temperatures. Sivyer Steel Casting Co., Milwaukee, Wis.

Published by the same firm, "Alloy Castings."

Die Casting Employed for Making Wide Variety of Parts.—Reprint from the Iron Trade Review. Article by Herbert R. Simonds. Illustrated. The Newton Die Casting Corporation, 146 Munson St., New Haven, Conn.

Vanadium Specifications.—1B, Specification "Carbon Vanadium Steel Billets for Locomotive Forgings," 2B, "Normalized Carbon Vanadium Steel Axles, Shafts and other Forgings for Locomotives and Cars," 3A, "High Test Vanadium Cast Steel Locomotive Frames," 4A, "Silicon Vanadium Steel Bars for Railway Springs," 5A, "Helical Springs of Silicon Vanadium Steel for Railways," 6A, "Chrome Vanadium Steel Bars for Railway Springs," 7A, "Elliptic Springs of Chrome Vanadium Steel for Railways," 8A, "Chrome-Vanadium Steel Bars for Automobile Springs," 9A, "Elliptical Steel Springs for Automobiles." Vanadium Corp. of America, 120 Broadway, New York, N. Y.

Published by the same firm, "Vanadium Steel Shows Strength," "Many Production Advantages Offered by Normalized Steel," "Alloy Steels Speed Industrial Progress," "Vancoram Chemicals," "Normalized Vanadium Steel Crankshafts."